THE NATIONAL CRITICAL MATERIALS COUNCIL

HEARING

BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

SECOND SESSION

JUNE 26, 1990

[No. 146]

Printed for the use of the
Committee on Science, Space, and Technology

U.S. GOVERNMENT PRINTING OFFICE

34-733 == WASHINGTON : 1990

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

H701-2

24-733 0 - 90 - 1

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

ROBERT A. ROE, New Jersey, *Chairman*

GEORGE E. BROWN, JR., California
JAMES H. SCHEUER, New York
MARILYN LLOYD, Tennessee
DOUG WALGREN, Pennsylvania
DAN GLICKMAN, Kansas
HAROLD L. VOLKMER, Missouri
HOWARD WOLPE, Michigan
BILL NELSON, Florida
RALPH M. HALL, Texas
DAVE McCURDY, Oklahoma
NORMAN Y. MINETA, California
TIM VALENTINE, North Carolina
ROBERT G. TORRICELLI, New Jersey
RICK BOUCHER, Virginia
TERRY L. BRUCE, Illinois
RICHARD H. STALLINGS, Idaho
JAMES A. TRAFICANT, JR., Ohio
LEE H. HAMILTON, Indiana
HENRY J. NOWAK, New York
CARL C. PERKINS, Kentucky
TOM McMILLEN, Maryland
DAVID E. PRICE, North Carolina
DAVID R. NAGLE, Iowa
JIMMY HAYES, Louisiana
DAVID E. SKAGGS, Colorado
JERRY F. COSTELLO, Illinois
HARRY JOHNSTON, Florida
JOHN TANNER, Tennessee
GLEN BROWDER, Alabama

ROBERT S. WALKER, Pennsylvania*
F. JAMES SENSENBRENNER, JR., Wisconsin
CLAUDINE SCHNEIDER, Rhode Island
SHERWOOD L. BOEHLERT, New York
TOM LEWIS, Florida
DON RITTER, Pennsylvania
SID MORRISON, Washington
RON PACKARD, California
PAUL B. HENRY, Michigan
HARRIS W. FAWELL, Illinois
D. FRENCH SLAUGHTER, JR., Virginia
LAMAR SMITH, Texas
JACK BUECHNER, Missouri
CONSTANCE A. MORELLA, Maryland
CHRISTOPHER SHAYS, Connecticut
DANA ROHRABACHER, California
STEVEN H. SCHIFF, New Mexico
TOM CAMPBELL, California
JOHN J. RHODES, III, Arizona

ROBERT C. KETCHAM, *Chief of Staff*
JOHN S. DOYLE, JR., *Chief Counsel*
CAROLYN C. GREENFELD, *Chief Clerk*
DAVID D. CLEMENT, *Republican Chief of Staff*

SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS

ROBERT G. TORRICELLI, New Jersey, *Chairman*

DAN GLICKMAN, Kansas
DAVE McCURDY, Oklahoma
BILL NELSON, Florida
TOM McMILLEN, Maryland
GEORGE E. BROWN, JR., California
(Vacancy)

TOM LEWIS, Florida
CHRISTOPHER SHAYS, Connecticut
DANA ROHRABACHER, California
TOM CAMPBELL, California

---

*Ranking Republican Member.

CONTENTS

WITNESSES

Page

June 26, 1990:

Dr. D. Allan Bromley, President's Science Advisor, and Chairman, National Critical Materials Council 2

Marc Newkirk, President, Lanxide Corp., USACA; Felix Fenter, President, Missiles Division, LTV Corp., AIA; Robert H. Gulcher, Vice President for Hypersonic Programs, Rockwell International, NASP; and Ronald L. Dieck, Vice President, R&D, Dow Corning Wright, Biomaterials 22

THE NATIONAL CRITICAL MATERIALS COUNCIL

TUESDAY, JUNE 26, 1990

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS,
Washington, D.C.

The subcommittee met, pursuant to call, at 2:05 p.m., in Room 2325, Rayburn House Office Building, Hon. Robert G. Torricelli, [chairman of the subcommittee] presiding.

Mr. TORRICELLI. The committee will come to order, please.

While we await members arriving from the last vote, the committee can proceed, mostly to hear my opening statement, which I know none of them were rushing to hear in any case. Undoubtedly, in fact, they delayed their arrival a few minutes to avoid it, but we did want to begin and appreciate, Dr. Bromley, your patience and those of the other witnesses in waiting for us.

The purpose of today's hearing is to oversee the National Critical Materials Council, with a special focus on the issue of advanced materials and our nation's advanced technological policies.

The Council, created by Congressional mandate in 1984, has responsibility for addressing critical materials issues primarily through coordination and policy leadership within the White House. As many of us are aware, critical materials, including advanced materials, are essential to the development of advanced technologies. Congress, in establishing the Council, wanted to assure the nation had an overall strategy for developing and applying these materials.

Today, of course, has special significance with the visit of Nelson Mandela. His appearance before the Congress this morning serves to remind us of the importance of South Africa and the internal problems they face. The Council has special responsibilities to assure viable alternatives to a continuing dependence on South African minerals which inhibit our foreign policy options. It is, of course, the case in other regions of the world as well.

I am pleased to note that Dr. Allan Bromley, the President's Science Advisor and Chairman of the Council, has recognized the importance of critical advanced materials. In earlier hearings before this subcommittee, Dr. Bromley listed materials technology, together with biotechnology and information technology, as deserving special focus by the Administration. However, we are yet to see any actions taken by the Council or Dr. Bromley to follow through with this earlier statement.

To my knowledge, the Council has not met in over two years, and continues to limp along with a minimum three-member staff, wholly inadequate to the tasks assigned to it by law. Those tasks include a report and recommendations for policy on critical materials, as well as updating of national advanced materials research and development plans. In the special area of superconductivity, a report with recommendations due this past March have been pushed off until the end of the summer.

It appears to me that we still lack commitment and leadership in this important area. Such leadership and commitment, unfortunately, and in my personal judgment, is not lacking among many of out competitors internationally. It seems clear that we must begin now to take steps in developing our own national strategic plans for advanced materials. Otherwise, we will continue to see more of our leadership in critical technologies erode, and the words "buy American" will refer only to real estate, hamburgers and other assorted cultural aspects of American life.

In addition to Dr. Bromley, we have assembled a panel of experts who will share with us the view of the opportunities and promise of advanced materials, which I believe are enormous, but which require national leadership to assure their realization.

I look forward to hearing their testimony and the discussions on these and related issues.

Because of some interest in the subject matter at hand, there has been a request for live coverage. I would ask, without objection, which is not anticipated, that permission be granted to cover this meeting by television, radio and still photography.

Dr. Bromley, I know that you have some time constraints. I would like, therefore, for my benefit and that of the staff and those in attendance, to proceed, if we could, even though we are still waiting for Mr. Lewis' and two other members' arrival.

So unless you object, I would appreciate it if you could proceed and summarize your remarks. They will, of course, be entered in the record in their entirety. I would invite you, as I'm certain you will, to respond to some of the statements that I've made about the Act, the Administration's activities to date and your intentions for the future.

Welcome and thank you for joining us.

STATEMENT OF DR. D. ALLAN BROMLEY, PRESIDENT'S SCIENCE ADVISOR, AND CHAIRMAN, NATIONAL CRITICAL MATERIALS COUNCIL

Dr. BROMLEY. Thank you, Mr. Chairman.

I do welcome this opportunity to appear before your committee to report to you on our plans for the National Critical Materials Council for this coming year. I am happy to be able to tell you that the full Council has now been appointed by the President. In addition to myself, as Chairman, we have Henson Moore, who is the Deputy Secretary of Energy, and T. S. Airy, the Director of the Bureau of Mines, as the other two members of the Council. We have scheduled our first meeting for July 9th, and I'm quite confident that we will have this activity off and running in short order.

I would pick up one of the points you made, Mr. Chairman, I believe very deeply that in many ways material science is something of an orphan, not only in Washington, but in the academic community, for the simple reason that it doesn't fit comfortably in the traditional academic department or in the—in many of the agencies that have part of the national program in material science and technology.

I do look on it as an opportunity for this administration and we will be working to develop and coherent, integrated national plan over this next year and more for material science and technology and Federal participation in that area of activity.

I'm particularly pleased to chair this Council because I think that it can play a very important role in conjunction with two other bodies, the President's Council of Advisers in Science and Technology, and the Federal Coordinating Council for Science, Engineering and Technology. Both of those bodies have already begun specific activities in this field, and so I would like, with your permission, sir, to report on some of these activities and how I think they hang together.

As I see it, there really are three important areas of concern for the Council. The first is the obviously important one of critical materials. The second has to do with advanced materials and the third, superconductivity and its potential in real applications.

The responsibilities of the Council in the first two areas have been detailed in the Critical Materials Act of 1984, as you mentioned, and the responsibilities for the Council in superconductivity are detailed in the Omnibus Trade and Competitiveness Act of 1988.

Let me begin then, if I may, with the area of critical materials. It's one of key importance, I believe, as do my colleagues in the rather dynamic setting to which you yourself have referred in today's world. By critical materials, I mean not only the conventional metals, but also the whole spectrum of materials that play a very important role in not only our national security, but our commercial, civilian competitiveness arenas.

We include here things like chromium, platinum, manganese and cobalt, as well as the large-volume metals, copper, aluminum and then move on to the more exotic composites, new materials about which you will hear more from a number of the witnesses that you've scheduled here today, and I regret, sir, that I will not be able to hear that testimony because I know many of the people involved and know something of the superb work they've been doing.

In 1988, the predecessor Council produced a report entitled, "Critical Materials Report." It is the intention of your present Council to begin, immediately following our July 9th meeting, to review and update that report. We do not believe that it is wise use of our time and resources to attempt to rewrite the report from scratch because much of it, in fact, is just as valid today as it was in 1988, but what we certainly will do is to review and update all the material that is covered there and expand as necessary.

Obviously, having the Director of the Bureau of Mines on the Council helps us in a very direct way, as does all the activity that goes on in the Department of Energy, and I know that both Mr.

Moore and Mr. Airy will play critical roles in the further work of the Council.

The sorts of things that I would suggest as possible new topics that we might want to take a look at would be the impact of the new clean air regulations on the demand for precious metals for use in catalysts, for example. The possible impact of the reauthorization of the Resources Conservation and Recovery Act on the recycling of materials, and quite frankly, sir, I believe that one of the greatest opportunities we face is in more imaginative, innovative use of science and of technology to eliminate waste so that we don't have to dispose of it.

Most of the waste streams from our industrial enterprise in this country are loaded with valuable materials, valuable chemicals, that can, in fact, be removed with processes that we now know about so that, in fact, it is not only environmentally, but economically sound to eliminate waste, rather than try to dispose of it. This, I think, is a real challenge, particularly in areas of critical materials because a number of them are ones that, in the past, have gone through our industrial process and in significant measure, have ended up in waste pools and dumps. I think we can do better than that.

Turning for a moment, then, to advanced materials, that really is the cutting edge of materials technology. These tend to be rather low-volume, but very high value-added materials. You will hear about a number of them this afternoon. Many of them have been created for niche uses, in the aerospace and in the military industries, where government's role has been very prominent.

And we're going to review in the advanced materials program plan that was produced by the previous Council in '89, and determine the areas that merit, in our view, particular attention. The review, I think, is particularly important in the light of what I consider to be an outstanding report that was produced under the chairmanship of Praveen Chaudhari and Mr. Flemming by the National Research Council in this past year, entitled, "Material, Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials."

This was a very extensive study and I think a very important one because it identified a major gap in American activities relating to materials. That gap was in the whole area of synthesis and processing, and if I could just take a moment to illustrate that, we in this country remain preeminent in the world in terms of our ability to develop new materials, new composites, new ceramics. We also are preeminent in the world in our ability to characterize materials, to talk about their microscopic structure, their property, their behavior, but time and time again, and more frequently with each passing year, in order to characterize the material that we have invented, we have to go to Japan to get a sample of it that has been synthesized at the level to which Japanese technicians are now capable and this is something that I think is something of a scandal and something that we obviously have to address.

Now, I have asked that in the regional meetings that are an outgrowth of this NRC report that the participants in the regional meetings come back to me and to OSTP with recommendations for specific actions that can be taken to bolster our standing in this

particular area. So this clearly is going to be an area of focus for the Council and for the other bodies that I mentioned to you.

Now, I need hardly remind you, Mr. Chairman, of the recent reports from the Departments of Defense and of Commerce, identifying technologies that the two Departments deemed of critical importance to competitiveness on the one hand and to national security on the other, nor need I remind you that although those reports in a number of areas of technology maintain that we still had a leadership position, the thing that was most distressing and most depressing about both reports was what they had to say about trends and the trends are that we are losing our leadership in many of these areas, more or less across the board.

This, obviously, is a matter of great concern to me, to my office, will be to the Council, and what we see as our goal is the matter of identifying actions that will create a better environment for materials commercialization.

One of the areas that we must devote attention to in the immediate future is the whole area of standards for testing of composite materials and parts. We're moving more slowly here, Mr. Chairman, than are a number of our competitors abroad. It is an area that is a legitimate one for government action and we are already meeting with representatives of various industries to look into what we can do to promote American leadership in this very important area of standards.

And lastly, let me turn, Mr. Chairman, to the area of superconductivity. Obviously, the excitement here dates to December 6th, 1986, with the announcement in Boston of high-temperature superconductivity, and there has been a rather surprising and, in a way, disappointing lag between the great flurry of interest that attended that announcement and the growth of applications for these new superconductors. I still believe, however, that there is a very important future and certainly have been watching very closely the very powerful concentrated program that the Japanese, in particular, are mounting in this particular area of high-temperature superconductivity.

Working under the Council, my predecessor Council, we had the National Commission on Superconductivity, and as you, Mr. Chairman, noted, that Commission is preparing a report. The report, in fact, is in final draft and will be in your hands shortly. It's now going through final review.

We will, as was the case last year, work to ensure that the activities of the Council and of my office, OSTP, work together in updating the action plan on advanced superconductivity, that we made available to you. This work, in my office, will fall primarily under the Committee on Materials, which is a part of the Federal Council for Science, Engineering and Technology.

And I would like, if I might, sir, to take a moment to tell you about the changes that have taken place in that particular area of activity.

Mr. TORRICELLI. Dr. Bromley, because I know that you have time constraints, there is a vote that's been called and I—what might be most efficient for your purposes, though not on my account, my time here is plentiful and cheap, is if you could end your formal remarks soon—

Dr. BROMLEY. Certainly.

Mr. TORRICELLI. —I'd like to then ask you several questions—

Dr. BROMLEY. Of course.

Mr. TORRICELLI. —because I'm afraid that if I leave to vote and I return, you will have departed.

Dr. BROMLEY. I have two very brief remarks, Mr. Chairman, and then I'm through.

The Federal Coordinating Council was established by congressional action in 1976 and I believe that we now have it working in the way in which you and the Congress had originally designed it. The problem in the past has been that the participation in that Council was at too low a level from the agencies and I'm happy to be able to report to you that we now have participation from a significant fraction of the Cabinet and from the heads of the remaining independent agencies.

We have seven umbrella committees, one of which will be working very intensively in the area of materials, science and technology, and then, because—the one gap that I see in that activity is that there's no formal mechanism for private-sector input. The President's Council of Advisors in Science and Technology provides an answer to that gap because that is a very distinguished group, a number of whose members have expertise in this area. Both of the groups, both FCCSET and PCAST, have now made major progress toward assembling specific groups working in materials, science and technology and we want to bring those activities together so we don't end up in government creating a camel that the private sector doesn't really want when we get done. So it's very important to get both of those working together and I see the Council playing a very important role.

PCAST will focus on the fundamental science questions. FCCSET will focus on implementing decisions that are made in PCAST and in the Council about putting together a coherent national plan and the Council will focus particularly on areas of materials science that are of major national importance.

With that, let me close.

[The prepared statement of Dr. Bromley follows:]

TESTIMONY OF D. ALLAN BROMLEY
CHAIRMAN, NATIONAL CRITICAL MATERIALS COUNCIL
BEFORE THE HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
JUNE 26, 1990

National Critical Materials Council's work agenda

It is a pleasure to be with you today to testify on our plans for the National Critical Materials Council (NCMC) in the coming year. First, however, I must point out that we have not had a meeting of the Council yet. We have scheduled an initial meeting for July 9, 1990. The slowness in forming the Council is not an indication that materials issues are viewed as a low priority by the Administration. The new, larger role that has been given to my office, namely that of Assistant to the President for Science and Technology, requires increased responsibility in many areas. The Council will be an integral part of the Administration's increased focus on science and technology, particularly with its role in materials science and engineering policy and related activities.

I am pleased to chair the Council because I believe this will help us to better coordinate activities on materials with the Federal Coordinating Council for Science Engineering and Technology (FCCSET), which I also chair. Therefore, in addition to the specific mission of NCMC as it relates to the enabling legislation, I want to discuss the role of NCMC in relation to FCCSET and the enhanced coordination of Federal materials research programs that this will promote.

There are three general areas that are of concern to the NCMC: The first area is critical materials, the second is advanced materials, and the third is superconductivity. The responsibilities of NCMC in the first two areas are detailed in the Critical Materials Act of 1984. The responsibilities of NCMC in Superconductivity are detailed in the Omnibus Trade and Competitiveness Act of 1988. I will describe a general program for each of the three areas.

Critical Materials

The examination of critical materials is an area of key importance in the dynamic setting of today's world. By critical materials I mean the conventional metals and other materials that have played such an important role in the defense and industrial base of this country. These include such metals as chromium, platinum, manganese, and cobalt; as well as the large-volume metals so important to the economy such as copper and aluminum.

In 1988, NCMC produced a Critical Materials Report. We will review and update that report. However, we do not think that it is a wise use of our resources, at this time, to repeat that entire report. Rather, it is better to chose specific topics of focus in the area of critical materials than to examine the whole broad field. The Bureau of Mines has ample information on all aspects of the field. We will work with the Bureau to fill in specific gaps in analysis that they may have identified, and provide for cross-agency coordination of critical materials issues. Possible topics could include: the impact of new clean air regulations on demand for precious metals used as automobile catalysts and the

possible impact of the reauthorization of the Resource Conservation and Recovery Act (RCRA) on the recycling of materials. We anticipate that recycling of materials will become increasingly important, and that it has the potential to increase the efficiency of production operations, and reduce the total volume of solid wastes that need to be sent to landfills and other disposal sites.

Advanced Materials

Advanced materials constitute the cutting edge of materials technology. They tend to be low-volume, high value-added materials. Many advanced materials are created for niches in the defense and aerospace industries -- where government's role is obviously prominent. We will review the Advanced Materials Program Plan that was produced by the previous Council in 1989 and determine the areas meriting particular emphasis. This review is especially important in light of the seminal 1989 study by the National Research Council, Materials Science and Engineering for the 1990's: Maintaining Competitiveness in the Age of Materials. I have asked that the regional meetings, which are an outgrowth of this report, consider recommendations for specific actions that can be taken to bolster materials science and engineering (MS&E) at a national level. Specifically, materials synthesis and processing has been identified as a key area of materials science and engineering needing increased attention. We anticipate that this will be one area of focus for the Council.

Recent reports by the Department of Defense and the Department of Commerce on critical technologies have included advanced materials. For this reason, the Council will

be providing an input to the OSTP report on critical technologies which will use the DoD and DoC reports as a starting point. While we still lead the world in basic research for many advanced materials technologies, many experts in the field acknowledge that many products are not commercialized quickly enough to compete in the global marketplace.

The Council will examine the issues that pertain to advanced materials and attempt to identify actions to help create a better environment for materials commercialization. For example, one area that comes to mind is the setting of standards for the testing of composite materials and parts. However, we are moving more slowly than our European and Japanese counterparts in developing testing standards for the industry. Facilitating the development of standards is a legitimate role for government, so we need to work with industrial groups to promote leadership in this area.

Superconductivity

As you know, superconducting materials in particular have captured the public's imagination. This is due to the discovery in 1986 of a new class of ceramic superconducting materials that lose electrical resistance at relatively high temperatures. The Council has been given the responsibility of staffing and coordinating the National Commission on Superconductivity. The Commission had their first meeting in October of last year. Since then they have met several times in order to produce a report and recommendations to the President and Congress. The work of the Commission will be finished sometime later this summer. I anticipate that the report of the Commission will

be a significant and influential contribution on superconductivity, and I believe that this Committee will find it to be of considerable interest. The Council will help coordinate any needed updates of the Commission's report.

As was the case last year, the Council will also work with OSTP in updating the National Action Plan on Advanced Superconductivity Research and Development. This update will be a primary function of the Superconductivity Subcommittee of the Committee on Materials (COMAT), which is part of our FCCSET structure.

Coordination with FCCSET

As noted earlier, I also have the privilege of chairing the Federal Coordinating Council for Science Engineering and Technology (FCCSET). By orchestrating the efforts of the NCMC and FCCSET we hope to achieve a level of coordination that will strengthen the materials program of the Federal government.

Let me briefly review the recent changes in the FCCSET structure. One of my major initiatives as Assistant to the President for Science and Technology is to revitalize and reorganize the FCCSET structure. I am very pleased and encouraged by the response and support of those Cabinet Secretaries and heads of independent agencies who are giving FCCSET their personal attention. We are proposing seven umbrella committees which will comprise the basic structure of FCCSET -- linking the full FCCSET council to the working level committees such as COMAT. Tom Murrin, Deputy Secretary of the Department of Commerce, chairs the Committee on Technology and Industry where

COMAT will reside. Dr. William Phillips, the OSTP Associate Director of Industrial Technology, is the OSTP representative to this umbrella committee. Dr. Phillips has an extensive background in materials and will provide valuable expertise in this area.

COMAT is embarking on a cross-cutting analysis of Federal research efforts in materials. We anticipate that this analysis will provide valuable information to decision-makers inside and outside the Government as to the deployment of resources in the pursuit of materials R&D.

The President's Council of Advisors on Science and Technology (PCAST)

In February of 1990 the Administration announced the appointment of the President's Council of Advisors on Science and Technology (PCAST), comprised of very distinguished scientists and engineers from the private sector. This is the first Presidential scientific advisory group in many years to provide high-level advice on a wide range of important issues. It reflects the commitment to further strengthen Federal science and technology policy and a recognition that advances in science and technology contribute in a major way to increased economic competitiveness. Some members have expertise in the materials science field and, where appropriate, their thoughts will be a contribution to our deliberations within the Government.

Providing the Proper Environment

The most important role that government can perform is providing the proper environment for the development of advanced materials technologies. This is

accomplished by supporting a vital basic research infrastructure, facilitating development of generic, enabling technologies where appropriate, and allowing the market to function efficiently when these technologies reach the commercial stage. As regards the conventional critical materials, we have to make sure that we safeguard the natural environment at the same time we ensure the strategic interests of the United States.

Conclusion

In conclusion, I know that I speak for the rest of the Council members when I say that we look forward to working with Congress in the areas of critical and advanced materials. Perhaps we will not always agree on what are the best policies to pursue; however, I am sure that we share a mutual interest in working together in a non-partisan manner to help to ensure the health of our Nation in critical materials and their related technologies.

Mr. TORRICELLI. Thank you, Dr. Bromley, very much.

You referred, of course, to the Critical Materials report. It was, of course, more of the intention of this Congress that it constitute a strategic plan of action. Is what we are to receive a report on current circumstances or a detailed plan of how it is those circumstances will be altered, assuming that they are?

Dr. BROMLEY. It is something of both. It is something of both, Mr. Chairman, because we obviously have to establish where we are at the moment to plan responsibly for our future actions, but I agree with you that clearly it is the responsibility of this group to focus on what we should be doing to maintain our position in a rapidly developing world marketplace.

Mr. TORRICELLI. Do we agree, Dr. Bromley, that a plan which simply notes the things that private industry should be doing and would be doing if market conditions were such and capital were formed, would not be adequate?

Dr. BROMLEY. It would not be adequate.

Mr. TORRICELLI. That, indeed, the role the government will play in bringing those forces together, adjusting the market conditions or directly using its own resources would be some of the elements that would have to be included?

Dr. BROMLEY. Indeed. A number of those elements—the questions of improving the environment are very important. The President addressed those in the budget he submitted to you and, subsequent to that budget submission in March, in a speech to the American Electronics Association, the President made it very clear that he believes that his administration has a very real responsibility for supporting the development of generic and enabling technologies which are closely related to material activities from the basic discovery up through the pre-competitive phase.

That marks a significant step forward, I believe.

Mr. TORRICELLI. On advanced materials, Dr. Bromley, if you could separate out elements of the process of discovery, innovative uses and productions, how would you differentiate American strength and weaknesses from the basic science of discovery, the formation of materials to their production, to their use in products? Differentiate—focus for me where you think the critical problems are.

Dr. BROMLEY. The most serious problem, sir, is one that I noted briefly before and that is simply that we have not maintained our strength, either in our academic institutions or in our industries, or for that matter, in the national laboratories, in the critical area of synthesis production. We still have a leadership position in terms of developing, innovating new materials and we still have a significant lead in terms of characterizing the ones developed, but in terms of producing them, making them available, conveniently, cheaply and in a reliable fashion so that our industries, large and small, can use them on the frontiers of material science, we have fallen behind.

Mr. TORRICELLI. There's something, Dr. Bromley, that's hard to understand about this and somewhat frustrating and we do have the world's largest aerospace industry. It is the world's largest consumer market and I've always believed it to be the most competitive consumer market, so from simple consumer products to the

cutting edge of high technology where these materials would be used, we have the market; there is the competition; there are the cutting-edge industries, that if the market were working properly should have America in the forefront.

Now, there may be changes in our academic institutions, but also the basic physics that is required in materials sciences, it's still my impression that while we may not have appreciable leads, we also in those institutions aren't second to anybody. Am I missing something here?

Dr. BROMLEY. Certainly not in the basic science at all. Either the development of the materials or in their characterization, but I think, to follow your main thrust sir, that the real problem, as I see it, is in part, at least, a reward structure problem, that we don't necessarily reward people for the kind of developments that are critically important to getting materials fabricated, to making the small developments that get us to the marketplace faster, more lively, cheaply and so on.

Mr. TORRICELLI. You mean that the market is not working to reward the enterprise or within the enterprise, the individual—

Dr. BROMLEY. No, within the enterprise, the structure—the reward structure is not—let me give you an example, two examples, if I might.

First of all, in Japan, in the area of superconductivity, for example, when the Japanese targeted that area, as they did within this past year, as one to which they were going to devote major resources for the indefinite future, they have targeted, first, that they're going to use it to demonstrate that they can do world-class basic research, but they've also targeted the areas where they're going to use it.

They're going to use it for large-scale electrical generation and they're going to use it for magnetically levitated transport. Now, they have put together a group under the same individual who was responsible for their development of very large-scale integrated circuits. He has pulled together a first-class team and that team includes materials experts; it includes manufacturing experts; it includes a whole spectrum of people quite different from what we would do in this country, and in particular, it includes what I would call super technicians, people who are among the world's best at doing what they do.

Mr. TORRICELLI. It seems to me, Dr. Bromley, that what it it that they have, in summary, is an industrial policy.

Dr. BROMLEY. No, I don't think so, sir. I would beg to differ on that.

Mr. TORRICELLI. How is this not elements of an industrial policy?

Dr. BROMLEY. What they have is a—

Mr. TORRICELLI. I have five minutes to go vote and this is what you call a 30-second answer.

Dr. BROMLEY. They have a long-term support policy for both basic and applied research that goes for 30 years. I have, in fact, just been handed recently the 100-year Japanese plan for their environment. We have nothing vaguely like that.

Mr. TORRICELLI. Dr. Bromley, this is an old debate between the two political parties, but industrial party—industrial policy does not require a supplanting the marketplace or instituting new

mechanisms. It can be no more than doing what you've outlined, and that is, target an industry as critical for national needs and bring resources, be they public and private, together. There is some notion in the administration that having a national industrial policy requires abandonment of our beliefs in free enterprise.

Indeed, it may do no more than simply use those resources in a more coordinated fashion.

Doctor, while we are waiting for this report/plan, is there anything this institution should be doing differently, more we should be doing, anything we should be doing that would be helpful?

Dr. BROMLEY. In the United States, sir?

Mr. TORRICELLI. Yes, lest it be said that any of the frustrations of the industry or the—

Dr. BROMLEY. Well, I think we're doing what we should be doing, namely, pulling together the best people we can nationwide, from both the private sector and from within government, to try to come up with a plan of action, not only an immediate one, but a strategic plan for the next number of years and then we want to bring this before you and we look forward to working with you to try and make this happen.

As I said at the beginning, I think it's an orphan area that deserves serious attention—

Mr. TORRICELLI. But Dr. Bromley, one thing we are going to do that I think will be helpful is we are going to have these get-togethers, I hope, with some frequency—

Dr. BROMLEY. I look forward to it.

Mr. TORRICELLI. —particularly as the report/plan is made available and we see its elements. We have allowed too much time to pass since this was recognized as an area of critical need. If this is indeed as important to the nation's future as you and I believe it is, then it is worth us getting together with some frequency.

I assume that when your authorization expires next year, the administration intends to ask for the Council to reauthorize?

Dr. BROMLEY. I would certainly expect so.

Mr. TORRICELLI. Good, we will do so.

Dr. Bromley, I'm going to go vote for a minute. The committee will be recess for only five minutes. We will be back promptly with colleagues in tow and we'll proceed.

Thank you for being with us.

Dr. BROMLEY. Thank you.

[Recess.]

Mr. TORRICELLI. The subcommittee will reconvene, please.

Dr. Bromley, during this last year, the funds the Congress made available for you to have additional staff to begin this construction of a national policy went unused, it is my understanding. Is that accurate and is there some reason why at this period the extent of the effort we're making didn't require the usage of staff?

Dr. BROMLEY. There are two parts to the answer, Mr. Chairman. The first is part of the reason that we will not use the full funding made available to us was simply because the new Council was not appointed until quite recently, and the second part of the answer is that we have, as I mentioned earlier, sir, put very extensive effort into getting materials science activities under way under both FCCSET and PCAST. Those are under way and so we did not move

forward as we would have otherwise under the Council because we were waiting to get the other Council members in place and I assure you that now that we have the full Council in place, I would certainly anticipate that we would use all the support that we can get.

Mr. TORRICELLI. Moving back to a conversation we had a few minutes ago, we had spoken of the Japanese model and I'd characterized that as a national industrial policy for critical materials on their behalf. Terms aside, would it be accurate to say that each of our principal economic and technological competitors are focusing on those advanced materials of concern to their industrial futures and mounting coordinated national efforts? I'm speaking of the French, Italians, Germans, British.

Dr. BROMLEY. I believe, sir, that all of those certainly—I'm aware of activities in all of those areas that are focusing on strengthening their ability to innovate in terms of materials science and technology and also to produce in those areas, no question.

Mr. TORRICELLI. So there are national plans?

Dr. BROMLEY. There are national plans.

Mr. TORRICELLI. If we were to characterize our situation, we may retain significant national advantages in basic science and in the development of some advanced materials, but in reaching a national strategy for advanced materials, we are finding that others have a leadership in their models.

Dr. BROMLEY. In certain areas, sir. It did, I think, come as something of a surprise to all of the people working in the materials science area in this country when the National Research Council report was issued, that it demonstrated as clearly as it did the weakness that we had in these areas of synthesis and production. It made that case in a compelling fashion and that's something that I believe that my office and my colleagues and I have a responsibility to try to do something about.

Mr. TORRICELLI. As you look at the programs in the Western European nations, are they looking at advanced materials primarily—and I recognize one can never say this exclusively—but primarily with an emphasis on existing consumer products along the patterns of their current trade or are these efforts to alter their industrial focus with an eye, for example, towards competitiveness in aerospace or electronic fields where they may not currently be competitive?

In other words, is it a strategy at maintaining current competitiveness or at widening their fields of competition?

Dr. BROMLEY. I don't have the specific information, sir, that would allow me to answer that in any direct fashion. I do not know, for example, enough about the details of the European activities to be able to say with the clarity that I can say it about the Japanese that they are targeting and are definitely focusing on improving their competitive stance.

I have not enough information to tell you the exact direction of the European strategic plans. I can tell you that they're putting more money into their research activities; that they are attracting bright young people into those activities—

Mr. TORRICELLI. When you say, "they," are you referring to European companies, European Governments or—

Dr. BROMLEY. Both.

Mr. TORRICELLI. —combinations thereof?

Dr. BROMLEY. Both. All of the above.

Mr. TORRICELLI. Industrial policy?

Dr. BROMLEY. I would again, sir, I think, quibble with the—perhaps with the definitions, but that's precisely what they're doing—

Mr. TORRICELLI. Maybe, Dr. Bromley, we've actually reached a critical point here in the relationship between the administration and the Congress because we've—perhaps we're finding that the administration has resisted our beliefs in industrial policy all these years because we've never really all understood what it is we were proposing.

The model that you've described previously in the Japanese model and now in the European side is exactly that to which we are referring. The idea that the government and whether it is simply a matter of strengthening departments of specific universities or aiding in long-term research over-the-horizon programs for companies and not justify that to their own stockholders or altering government purchasing or, in a question that I want to address next, in setting standards, nevertheless is moving an industry or a technology further than the natural forces in the market at that time would otherwise yield a result.

To me, that's all industrial policy has to be. I don't think theoretically, whether it is in this conversation you and I are having today, or in conversations with an HDTV or semiconductors we've had with others on other dates, you necessarily disagree with the elements of that strategy.

Dr. BROMLEY. No.

Mr. TORRICELLI. It is somehow this term that brings fire to your eyes.

[Laughter.]

Dr. BROMLEY. Not quite, sir, but let me try to—let me try to perhaps clarify a bit.

Many of the components you've just listed, I have no quibble with whatsoever nor does this administration. But the administration's position is that it does wish to be in a position of trying to second-guess the private sector in terms of picking specific industries as winners or losers or specific components of a given industry.

But we are thoroughly behind using the power of the Federal Government in all the ways available to us to strengthen our science and technology base, to develop the generic technologies, to help companies work together, to cooperate, to reduce the costs, to reduce the risks, to shorten the time. We simply can't compete in the world market as you, yourself, sir, indicate if we require our companies to reinvent the wheel on every opportunity, which, in fact, in the past, was probably the case.

Mr. TORRICELLI. I guess, Dr. Bromley, that's the point and I'm making it not to prolong the discussion, but that I know, not only in this question, but on so many of these cutting technologies, you participate in the administration's decisionmaking in those elements.

And it's important for us to understand that the gap between us philosophically is not—is not wide. I know of no one in this institu-

tion that is proposing a national strategy where we pick winners and losers. So every time the notion of industrial policy comes forward, it is charged that somehow Democrats or Members in Congress generally want to enter into the marketplace and substitute our judgments for those of purchasers and sellers.

I don't care which of these products—which of these companies that make advanced materials succeed. I don't know any of the executives in them. I don't own any stock in them. Few of them are in my area. I really don't care. All I care is that someone succeed in the country and all we're trying to do is advance the technology, not an individual company. They can rise or fall on their merits as it is, but yet, somehow this discussion never gets further than those points.

Let me finally, before I let Mr. Rohrabacher continue, the question of setting standards. Now, if ever there were a legitimate role that even Adam Smith would agree the government could play a role in here. It is in setting the standards of what these materials must be, their consistency, their performance. That is both an important element in international competition because we can set standards to our own levels. It, of course, is not only good for advancing our own technologies, it is good protection for the public. Do we agree that as the elements of this plan is coming forward, the setting of standards for advanced materials is a legitimate, proper and, in some cases, timely function?

Dr. BROMLEY. Absolutely.

Mr. TORRICELLI. Good.

Thank you, Dr. Bromley.

Mr. Rohrabacher.

Mr. ROHRABACHER. What was the term you used, fire in your eye, or—I've got these fires coming up in my eyes.

[Laughter.]

Mr. ROHRABACHER. Speaking about national industrial policy, do you think that when Congress gets involved with developing national policy about materials that it might tend, with political pressures, to side with industries that are already developed and maybe on the way down, for example? Wouldn't—do you think if we had a national industrial policy, wouldn't it have favored the steel industry and heavy metal, at the expense of developing new industries that didn't already have constituencies if we—just because this is a democracy and that's the way it works out sometimes in a democracy?

Dr. BROMLEY. Sir, I would not dare to try to predict the actions of the Congress.

[Laughter.]

Mr. ROHRABACHER. Thank you.

I'd like to ask you a little bit about ceramics and the National Aerospace Plane and some of the progress we've had on that end.

Could you fill us in—I'm sorry, we were over there voting and—

Dr. BROMLEY. I understand, sir.

Mr. ROHRABACHER. —I missed the beginning of your statement.

Have there been some new materials developed by the National Aerospace Plane program that you think are going to really be beneficial to America across the board, industrially?

Dr. BROMLEY. I have been very interested and very impressed by the work that is being done in the NASP program in developing super-light, super-strong materials and there's no question in my mind at all, sir, that these materials, once developed in that program, will find extensive application outside of the specific area of development.

This is an important part of our national effort in materials science, right at the cutting edge.

Mr. ROHRABACHER. For example, not too long ago, we were very dependent on countries like South Africa and the Soviet Union for things like chromium and, I guess platinum and things such as that. Are the new materials that we're developing with National Aerospace Plane and some of the other projects, is that actually a great benefit to American security?

Dr. BROMLEY. Well, in some—certainly there is no question that the work that's being done is very important to American security. In the areas that you specifically mentioned, chromium and platinum, we have, as I see it, two major challenges. We have, first of all, the question of materials replacement. Platinum and chromium have very specific elemental properties that fit them for the kind of applications with which we're all familiar.

We have, I think, the opportunity to find replacements that are domestically available for many of the applications for chromium or platinum, but there will always remain some. For example, catalytic properties depend on particular elemental properties that you simply can't substitute directly.

What we can do, however, is use the chromium and platinum that we have vastly more efficiently than we are doing at the present. Much of the chromium, much of the platinum that we have as an input to our industrial enterprise ends up in waste. We can now—we have the technology now to recover all that, to recycle it, to reuse it and I think that we have to take—we do have a world leadership position, incidentally, right at the moment in this waste-elimination process. It's going to be, in my view, a growing industry and a very important one, and I'm excited about the potential that there is in that area.

Mr. ROHRABACHER. Just to summarize, are you—when you look at comparative—what we were looking at 10 and 20 years ago and people were saying, "We're entering this era of scarcity and we're going to use up everything and we've got to lower our expectations," and in the last—that whole picture has changed in the last 10 or 15 years, hasn't it?

Dr. BROMLEY. That's right. That was the limits-of-growth syndrome and I didn't believe it then, I don't believe it now. I have a lot of faith in what science and technology can do. We can, if we simply use what we now know, quite apart from what we will discover in the future—we have the ability to recycle the materials of the earth's crust that we require, to recycle them indefinitely. The time is rapidly coming when we can find it profitable, economically, environmentally, to mine many of the waste dumps that we have in this nation.

Mr. ROHRABACHER. If you were going to put a statistic on it or a figure on it, would you say that, in the last 10 years, the progress

in this area has been, as compared to what had taken place, what, in the hundreds of years before or—

Dr. BROMLEY. The progress throughout all of science and technology is growing exponentially. It's accelerating.

Mr. ROHRABACHER. What about in terms of materials that specifically—

Dr. BROMLEY. In terms of materials themselves, obviously one of the most exciting developments was high-temperature superconductivity in '86, but that's not the only one. We are going to hear later this afternoon about what I think are some enormously exciting developments in metal-reinforced ceramics and ceramic-reinforced metals, for example. We have the whole area of composites, where we've learned how to us fibers of carbon, boron, to obtain materials that have strength beyond that of most steels and yet have relatively light weight and can be used in applications that would simply have been quite impossible with the materials we had a decade ago.

Mr. ROHRABACHER. I just hope—one last thought is that we don't get so excited about setting policy that we get government so involved in the development of these things that it messes it up like it does everything else it gets involved in.

[Laughter.]

Mr. ROHRABACHER. Thank you very much.

Dr. BROMLEY. Thank you, sir.

Mr. TORRICELLI. Thank you, Mr. Rohrabacher, I think.

Dr. Bromley, finally, I hope that next year we're not here with—asking your comments on the congressionally led critical materials initiative because we've received the report and find that it is a simple analysis oi a problem, calling upon the spirit of enterprise and the American stockholders to come forward and put their dollars in place. I hope it's more than that. I hope it's a genuine plan. I hope it's an initiative so we don't spend another year and then go through this exercise of you accusing us of picking losers and winners and we accuse you of abandoning the nation's technological future, that we've been through that exercise a lot of times. It doesn't produce anything.

What we want is to know that there's a plan. That's what the law requires. That's what we've asked you to do. We've given the materials for you to plan it. I've asked you if there's anything else you need from us in the interim to assist with that. It appears to me that you don't. We're eagerly awaiting the plan and hope you can make it work. There's an awful lot that depends on it.

Do you have any final thought you'd like to share with us?

Dr. BROMLEY. One bit of clarification, sir. That is, I want to emphasize that we're doing the critical materials report, which is essentially a status document. We're doing an advanced material plan, where we have a strategy for moving forward.

Mr. TORRICELLI. That was my—

Dr. BROMLEY. I don't want them to be confused.

Mr. TORRICELLI. I understand.

Dr. BROMLEY. Thank you very much.

Mr. TORRICELLI. Thank you, Dr. Bromley, very much.

For our next and final panel, if we could, Marc Newkirk, President, Lanxide Corporation; Felix Fenter, President, Missiles Divi-

sion, LTV Corporation; Robert Gulcher, Vice President for Hypersonic Programs, Rockwell International; Ronald Dieck, V.P., R&D, Dow Corning Wright.

Thank you, gentlemen, for your participation today. I appreciate your help before the subcommittee. Your comments will, of course, be entered into the record in their entirety. We would like to reserve as much time as possible for a discussion of these various issues; therefore, we'd ask you to be brief, to summarize, to reach of your major points and then we can develop them further, if we could.

Mr. Newkirk, would you like to proceed.

STATEMENTS OF MARC NEWKIRK, PRESIDENT, LANXIDE CORPORATION, USACA; FELIX FENTER, PRESIDENT, MISSILES DIVISION, LTV CORPORATION, AIA; ROBERT H. GULCHER, VICE PRESIDENT FOR HYPERSONIC PROGRAMS, ROCKWELL INTERNATIONAL, NASP; AND RONALD L. DIECK, VICE PRESIDENT, R&D, DOW CORNING WRIGHT, BIOMATERIALS

Mr. NEWKIRK. Mr. Chairman, I thank you on behalf of the United States Advanced Ceramics Association, and the committee, for the opportunity to address you on the, I think, very relevant and appropriate subject for this committee, of advanced ceramics.

Mr. TORRICELLI. Mr. Newkirk, maybe if we—I appreciate you doing that for my benefit and for the committee's, but perhaps you could turn it a little bit so people in the audience could see the screen as well. Could you turn it so it, in fact, is parallel to the wall?

Mr. NEWKIRK. How's that?

Mr. TORRICELLI. I think it will work fine. Thank you.

Mr. NEWKIRK. Advanced ceramics represent a critical area of enabling technology which we believe will broadly drive U.S. industrial competitiveness and world industrial competitiveness over a broad range of the industrial base. By advanced ceramics, we're referring to not only monolithic ceramics, but ceramic matrix composites or ceramic reinforced ceramics, ceramic-reinforced metals and ceramic-coated materials.

Advanced ceramics, as a class of materials, are the lightest-weight, strongest—are the lightest weight class of strong tough materials which also, at the same time, possess a—the greatest capacity for being chemically inert. They are the most corrosion-resistant class of materials. They are the hardest class of materials. They are the most rigid class of materials and the most temperature-resistant class of materials.

As such, they will greatly drive industrial competitiveness over a broad range.

We live today in a very sophisticated age where we have engineered the traditional materials within a short degree of their capacity in system after system after system throughout our society. Typically, we're now down to the point of trying to squeeze the last percent or two of performance improvement out of sophisticated systems.

If we want to see quantum improvements, major improvements, in systems today, we have to make fundamental changes in the

materials on which those systems are constructed. The class of advanced ceramics as a class of materials offers the potential for quantum improvements in terms of energy efficiency, productivity of manufacturing processes, product life and product durability, speed and maneuverability of many systems, and compactness.

Advanced ceramics is, in fact, a keystone enabling competitiveness across the broad industrial base and here I've illustrated many such industries: automotive, aircraft, machine tool, et cetera, and we foresee that this class of materials will, in fact, drive competitiveness more than any other area of technology. This class of materials offer the potential for such diversity as dramatic improvements in everything from aircraft to golf clubs, electronic devices, to steel production efficiencies.

For this region—this reason, this class of materials represents a—an area of technology which has been targeted by all of our major trading partners and is of major strategic importance to this nation.

This is very much, therefore, in our view, a battle which we cannot afford to lose. We believe what's at stake in the success or failure of leadership in this area of technology are, in fact, the underpinnings of the U.S. economy. The industrial competitiveness of the United States across broad industries, and the ultimate impact on jobs in the issue of how we fare in that competitiveness.

Additional issues at stake include national security, where our military competitiveness is also dependent upon these advanced materials.

To understand the issues for our industry, I offer this illustration here. This is a graph, if you will, of product cost as a function of time over the maturity curve of advanced materials typically. And typically, what we see is from the point of initial concept to full commercialization, typically we're looking at a decade or more of time frame in order to move down that experience curve.

At the same time, what happens, as you move through the various phases from concept to laboratory stage, to pilot phase, to early commercial and full commercialization, is that the product cost decreases. You start off in a laboratory with a concept in advanced materials which may involve materials of the order of $10,000 a pound made by a few Ph.D.s in a laboratory, and as you proceed down the experience curve, making larger volumes of product, improving your engineering processes, improving the materials technology and penetrating the market and starting to generate a large industrial base of application, the product cost drops. And I won't debate with you exactly what level it would be into, depending upon the specific materials, but something of the order of a 1000-fold decrease in cost would be typical for advanced materials in moving from concept stage to full commercialization stage.

The problem, Mr. Chairman, for our industry is that the markets which exist short of the full commercialization stage, short of being very largely down that experience curve—are too small to justify in their own rights the investments necessary to move down that experience curve by the private sector when one looks at commercial markets alone.

These—the area represented in red here, as shown on this curve, the area between a few hundred dollars a pound and maybe $10 a

pound for these materials represents areas of markets which are very small in the commercial sector. They're only of major consequence when one comes to, frankly, the government markets.

We have a unique problem for our industry, which USACA has dubbed the "bridge problem", namely that of moving down that experience curve, given its long time and its massive investment requirements. Due to the sophistication of the business, the critical dependence of the systems businesses upon these class of materials—the production efficiencies which are achieved only in high volume, we have a unique problem in trying to move down this experience curve.

The U.S. industry, frankly, is very poorly positioned to win without government strategic involvement in this area. We do, in fact, have leading technology in this area and the U.S. continues to lead in innovation. However, we have a higher cost of capital by as much as a factor of four versus foreign competition. We have a poorer debt capital leverage by as much as a factor of five versus foreign capital—versus foreign competition—and we frankly have a unique disease in the North American industry over the inability to make long-term strategic investments, owing to the ownership structure of our industry as compared with foreign competition.

The combination of all of that creates a great importance for this industry in government involvement. The government represents the largest and really only viable prospective market for economically immature technology. The Department of Defense, as a customer of advanced technology, as an example, NASA also and others, represent a large market upon which this industry is critically dependent.

We see the government role as critical in balancing our position versus foreign competition in this strategically critical area. We see the government—the need for government involvement not as one of subsidizing noncompetitiveness, but rather, as facilitating competitiveness in this industry in balancing our position.

We believe the total programs in the advanced ceramics area of the order of $200 million a year in government funding to industry, in a combination of programs, will directly facilitate the creation of an industry 100 times that size and enhance the competitiveness of industries 10,000 times that size.

We see that government role being involved in increasing funding for technology development and demonstration programs. We have, Mr. Chairman, already, a number of critically important programs under way. We need to do more of that, make more investments at the front end of this experience curve. We feel that in a zeal to take an axe to the defense procurements budget, it's important to represent—to recognize that the Department of Defense does, in fact, represent the largest market for economically immature technology, and it's important to provide procurement markets which can draw on this technology and pull us down the experience curves.

Lastly, we believe it's important to develop and maintain industrial investment incentives; that is, the incentive of the industry to make its investments in this area by having effective patent and technology rights and policies associated with the government programs.

[The prepared statement of Mr. Newkirk follows:]

UNITED STATES HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS

HEARING ON THE NATIONAL CRITICAL MATERIALS COUNCIL

JUNE 26, 1990

TESTIMONY OF

MARC S. NEWKIRK

PRESIDENT AND CHIEF EXECUTIVE OFFICER

LANXIDE CORPORATION

PRESIDENT

UNITED STATES ADVANCED CERAMICS ASSOCIATION (USACA)

TESTIMONY OF
MARC S. NEWKIRK
PRESIDENT AND CHIEF EXECUTIVE OFFICER
LANXIDE CORPORATION
NEWARK, DELAWARE

Mr. Chairman, I am Marc Newkirk, President and CEO of the Lanxide Corporation. My appearance before the Subcommittee today is in my role as President of the United States Advanced Ceramics Association (USACA). USACA represents more than thirty five American manufacturers and consumers of advanced ceramic products.

I would like to thank the Chairman and the Subcommittee for the opportunity to testify on issues which I believe strike at the very heart of America's prospects for future industrial competitiveness. It is this simple realization -- of the absolute criticality of the advanced ceramics industry -- that I would, above all, hope to impress upon you today. I would also hope to leave you with some thoughts as to what the Federal government might do to enhance the viability of our domestic advanced ceramics industry.

The criticality of advanced ceramics becomes clear when one considers that, in the intensely sophisticated environment in which we live, the performance of almost any system one can name -- electronic equipment, automobiles, aircraft, machine tools, steel and chemical process plants, to name a few -- has been engineered very nearly to the absolute limits feasible given the properties of the materials out of which they are currently constructed. Significant further improvements in system speed, compactness, durability, energy efficiency and so on can only be realized by the substitution of an entirely new class of materials with fundamentally different properties than those presently employed.

Advanced ceramics are such a class of materials. Their temperature resistance, hardness, chemical stability and higher rigidity give them a unique capacity for extending the performance parameters of existing systems, in many cases, by quantum leaps. I would challenge the Subcommittee to identify another technology that provides such an enormous and pervasive capacity to influence future industrial competitiveness.

The strategic importance of advanced ceramics has not, of course, been lost on our foreign competitors. The member companies of USACA are in the midst of a very real and very tough battle with foreign counterparts whose governments have targeted advanced ceramics as an industry they seek to dominate.

Before describing some of the ways in which the Federal government can help our domestic industry compete with its rivals, let me first enumerate some simple facts of American corporate life which complicate the defense of any industry targeted by countries such as Japan.

Firstly, it has become almost axiomatic to say that American industrials lack the ability to make major long-term, strategic investments. While this is true, the reasons for it are usually -- and inappropriately -- ascribed to stupidity or shortsightedness in American boardrooms. In truth, our inability to invest strategically is a result of a fundamental change in the ownership structure of American business.

Twenty to thirty years ago, the majority of corporate stock was held by individual investors who were willing to suffer the short-term financial set-backs (i.e. reduction in or loss of dividends) that can be caused by major commitments of resources to strategic investments, such as emerging technology. Today, the majority of corporate stock is held by institutional investors such as mutual funds and insurance companies. These investors are, by their very nature, intolerant of any corporate activity that hurts quarterly financial returns. The primary measure of success in mutual funds is quarterly earnings. Fund managers are not interested in making a long and potentially painful "climb" with a company even if they believe the "view", ultimately, might be worth it. Such tolerance would cause them to lose their constituency which "votes" by cashing out of the fund when quarterly earnings are reduced.

By contrast, the ownership structure of Japanese industrials -- large collections of businesses linked by interlocking boards and shareholdings -- allows for and encourages long term strategic investments. If the goal is to establish market dominance in a critical, targeted industry, our Japanese counterparts are willing and able to swim in the red ink associated with getting there.

Furthermore, not only is Japanese capital almost infinitely patient, it has been obtained typically at one quarter the cost of capital in this country. And because of the lower risk environment associated with a managed economy, our Japanese counterparts have five times the leverage of lower-cost debt capital versus American companies.

Despite these major operating disadvantages, there is still hope for the domestic advanced ceramics industry. Contrary to popular belief, the U.S. does, in fact, have an edge in some of the more promising materials technologies such as ceramic and metal-matrix composites.

The challenge we face is in successfully converting this technological edge into industrial competitiveness. To succeed, American industry will need to work hard and work intelligently. But we will also need the cooperation and, in some cases, the strategic assistance of the federal government. This is the strong conviction of the United States Advanced Ceramics Association.

More specifically, our industry needs the cooperation and assistance of the federal government in:

1) evening out the "playing field" by absorbing more of the front end financial risks by increased funding for technology development and demonstration programs;

2) implementing policies and adopting budgets which utilize the enormous procurement capacity of the Department of Defense to create more economically attractive, effective "bridge" markets for economically immature critical technologies, promoting early industrialization in these areas and allowing the industry to profitably progress down the experience curves associated with manufacturing; and

3) the development and maintenance of industrial investment incentives through effective patent and technology rights policies.

These and other proposals are part of a broader, USACA-sponsored "Bridge the Gap" program which seeks to deal comprehensively with the issues of greatest import to our advanced ceramics industry. A copy of this program is attached to my testimony.

Where does the National Critical Materials Council fit into all of this?

There is an obvious need at the federal level for oversight and coordination of budgets and policies pertaining to ceramics and other advanced materials. The Council should provide this function and service as the Administrations spokesperson or ombudsman for the advanced materials industry. Clearly, such a role would include integrating the various recommendations made by the NRC with the concerns identified in the critical/emerging technology report of the Departments of Defense and Commerce.

I would hope that, in the execution of its charter, the Council would consult regularly with industry and strive to make its efforts meaningful on commercial as well as technological or scientific basis.

34-733 0 - 90 - 2

USACA

UNITED STATES
ADVANCED CERAMICS ASSOCIATION
Suite 300
1440 New York Avenue, NW
Washington, DC 20005
Telephone 202 638-1200
Fax: 202 639-8685

ADVANCED CERAMICS DEVELOPMENT AND COMMERCIALIZATION PROGRAM

In order to reach the goal of supporting and creating a strong and viable domestic advanced ceramics industry, the United States Advanced Ceramics Association has created a six-point **Advanced Ceramics Development and Commercialization Program**, that includes support for legislation and governmental policies that will:

1. **Create a multi-year Federal Ceramic Components Demonstration Program** that would support the domestic development, manufacture, purchase and in-use demonstration of advanced ceramic components and parts over a five-year period. This program would target military and commercial advanced ceramic areas, including: automotive; structural aerospace; aerospace propulsion; electronics (semiconductors); machine tools (including cutting tools); additional weapon systems (e.g. armor, gun system, vehicle track); component applications, and industrial process equipment.

2. **Create a Defense Production Act (DPA) Title III Advanced Ceramics Program.** This program would take the form of purchase commitments (guarantees) to buy ceramic components produced by domestic advanced ceramics manufacturers for incorporation into various military systems.

3. **Create and expand investments in domestic advanced ceramics manufacturing science and technology programs** aimed at demonstrating cost-effective production and reproducibility of advanced ceramic components focused upon specific requirements of end-users.

4. Recognize the capital intensive nature of the advanced ceramics industry and promote industrialization in this area by:

   a. allowing a more competitive return on advanced ceramics components purchased through the Federal procurement system and;

   b. permitting first-year write-down of those new capital investments made by the advanced ceramics industry during the next ten years.

5. Provide incentives, such as Government-funded rebates or tax incentives, for domestic advanced ceramic end-users who incorporate advanced ceramic components in products and demonstration programs during the next decade, so as to provide user "pull through" to the U.S. advanced ceramics industry.

6. Mandate the vesting of technology rights in advanced ceramics to domestic advanced ceramic manufacturing contractors when they participate in R&D, Man-Tech and Demonstration programs on a cost-shared basis, in order to attract and promote the most commercially attractive and innovative technologies in these efforts.

Mr. TORRICELLI. Thank you, Mr. Newkirk.

Mr. Fenter.

Mr. FENTER. Mr. Chairman, you mentioned that I am President of the Missiles Division of the LTV Corporation. However, this afternoon, I'm here representing the Aerospace Industries Association, where I am the chairman of the Technology and Operations Council, so I represent much more than my own operation today.

The Aerospace Industries Association, as you know, is composed of some 54 of the nation's major aircraft, helicopter, aircraft engine, missiles, spacecraft and other related type companies. It virtually represents the entire industry.

And, of course, the entire industry is greatly concerned about the current U.S. technology base and our industry's future global competitiveness. As a result, some four years ago, I would guess, our—the AIA took the bit in its teeth, if you will, and the various industries involved initiated a national cooperative effort involving not only industry, but also government and academia and we called that the "Key Technologies for the Year 2000."

This effort involves a three-pronged initiative. First, we formed the Aerospace Technology Policy Forum, which is made up of high-level policy leaders from industry, government and academia. This forum addresses key technology issues as they relate specifically to national policy. Dr. Bromley, for example, is a member of that Policy Forum.

The second element of our three-pronged initiative is the National Center for Advanced Technologies, and the acronym for that is NCAT. NCAT is an AIA-sponsored foundation that coordinates with a full-time staff, the day-to-day activities of the entire key technology program and they provide the focal point for integrating all of these activities into a coherent national program.

Well, the third, final and most important element of the initiative involved the establishment of a technology team for each of the identified key technologies. Now, these teams, from all over the country and from a cross-section of our industry, set objectives. They developed specific road maps and they evolve implementation plans for each of the key technologies that we have identified.

Even though this program is an industrial initiative, these key technology teams also include government and university experts. There are currently 10 key technology teams at work, including one which addressed advanced composite materials, which I'd like to say a few words about today.

As the AIA sponsor of the advanced composite materials team, I think I can state with confidence that advanced composites research certainly has a high pay-off leverage as well as broad application to both commercial, as well as military aerospace applications. I think we're all aware of that.

The composites road map for advanced composites was released in the May—in May of 1989, last year, outlining the tasks that we believe are required to develop a national technology plan that would take us well into the 21st century. It is a long-range plan.

A copy of this road map is being submitted for the record.

[The information follows:]

A Detailed Technology
Roadmap for

COMPOSITE MATERIALS

KEY TECHNOLOGIES FOR THE 1990s

Aerospace Industries Association of America, Inc.

A Detailed Technology
Roadmap for:

COMPOSITE MATERIALS

ROADMAP SPONSOR: F. W. Fenter, LTV Missiles Division

COMMITTEE MEMBERS:
W. S. Cebulak, Alcoa Laboratories
J. Cornie, Massachusetts Institute of Technology
J. D. Dorr, McDonnell Douglas Corporation
C. H. Haight, LTV Missiles Division
M. Kinna, Office of Naval Technology
F. K. Ko, Drexel University
J. Persh, Office of Deputy Director for Research & Engineering
R. B. Pipes, University of Delaware
T. Ronald, NASP Joint Program Office
J. Strakosch, Grumman Aerospace Corporation
R. C. Van Siclen, LTV Missiles Division
S. Venneri, NASA Headquarters
R. Whitehead, Northrop Aircraft Division

MAY 1989

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.
1250 EYE STREET N. W. WASHINGTON, D. C. 20055

TABLE OF CONTENTS

Foreword 1

Composite Materials Introduction 5

Resin Matrix Composites 10

Metal Matrix Composites 30

Carbon/Carbon Composites 48

Ceramic Matrix Composites 66

Composites Integration 84

Summary and Recommendations 87

Appendix 99

34

FOREWORD TO THE AIA KEY TECHNOLOGIES FOR THE 1990'S INITIATIVE

Background

The United States technological superiority in aerospace products and military capability is being severely challenged. Although the industry has consistently maintained a substantial positive trade balance, aerospace imports are growing rapidly and U.S. aerospace competitiveness is eroding.

Our national defense requires affordable systems and a robust capability to provide strong deterrence. Our national economic well-being depends on competitive high quality products and the jobs, tax base, and positive trade balances they create. These national goals can be furthered with a bold, innovative national technology development program leading to superior U.S. aerospace products.

The AIA Proposal

The Aerospace Industries Association initiative called Key Technologies for the 1990s proposes a three-pronged national strategy. The first thrust is to create a cooperative national effort among industry, government, and academia to focus on the development of selected key technologies. The second is to cooperatively mold innovative policies that will stimulate technology development and facilitate its rapid application into new commercial and military products. The third thrust will focus on development of methodologies, tools, and disciplines required to enhance competitive use of our technology base. AIA is committed to a leadership role, working cooperatively with government and universities. The goal is to ensure U.S. superiority in aerospace products and military capability well into the 21st century.

Key Technologies List

Over the past few years senior technologists in the AIA member companies reviewed over 100 technologies for future applications to systems. During the past year, they achieved a consensus on eight key technologies which need immediate and special attention. These eight technologies were selected on the basis of highest leverage, greatest potential payoff, and broadest application. If an adequate national focus can be attained, and if they can be protected from severe budgetary perturbations over the long haul, together these eight key technologies can result in markedly superior products for the global marketplace:

Composite Materials
Very Large Scale Integrated Circuits
Software Development
Propulsion Systems
Advanced Sensors
Optical Information Processing
Artificial Intelligence
Ultrareliable Electronic Systems

AIA representatives have prepared a draft Roadmap for each of the eight key technologies. Working with government and university representatives, the Roadmaps will first be validated, then refined into Technology Development Plans. These plans will give a joint perspective of the state of each technnology, the plans for progress, resources currently being used, and those required to meet future goals.

Implementation

AIA envisions a long-term effort to emphasize national development of the Key Technologies for the 1990s. Concurrent with the Roadmap evolution, a joint policy level group called the Aerospace Technology Policy Forum will oversee the technology team efforts and review regulations, policies, and legislation needed to facilitate technology development.

AIA needs and solicits strong institutional and individual support for its proposal for national action. If U.S. competitiveness is to be meaningfully enhanced, leaders of industry, government, and academia must all contribute to renewing the national spirit of cooperation and partnership. The challenge is to make such an organized national technology development effort work as never before in peacetime.

5-15-89 LMBY 7014

ROADMAP SUMMARY AND RECOMMENDATIONS

SJ22/89-1MB9-203 55

Composite Materials Summary

Composite materials have demonstrated the potential for dramatic improvements in the performance of aerospace structures. While a great deal has been accomplished, especially with regard to the resin matrix composites, it is important that a concentrated technical effort be pursued on a national effort to ensure that the competitive position of the U.S. aerospace industry remains strong. Currently, a number of other nations are making dramatic moves in the area of composite materials that ultimately will erode the U.S. position. For future system performance requirements, the tasks outlined in this roadmap must be performed.

There is a vital need for a combined effort between U.S. academia, industry, and government to ensure that the necessary resources be available to accomplish the goals outlined. There is a strong requirement for skilled manpower, in addition to equipment and financial resources.

40

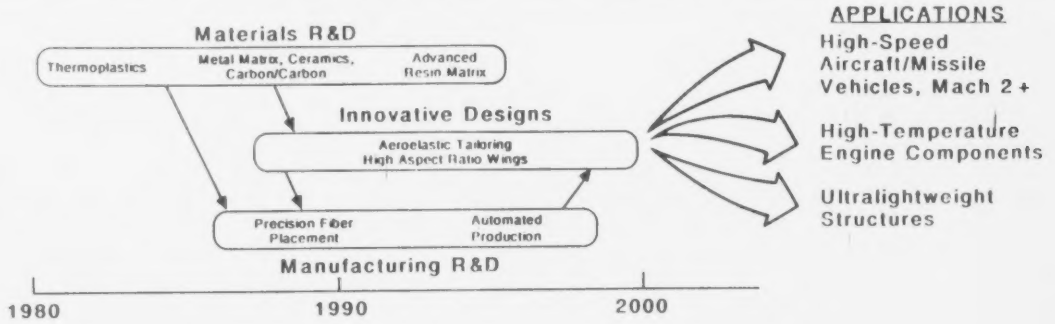
Composite Materials Overview

Composite materials offer tremendous potential for meeting the performance goals of future aerospace systems. This need exists to develop all four categories of composites covered in this roadmap. In the case of the resin matrix composites, emphasis should be placed on more innovative design/analysis, improved producibility, greater durability, and overall enhancement of the affordability of the finished component. For the three other composite material categories, because of their current state of development, emphasis must be placed on the evolution of material systems, some just appearing today, that will realize the tremendous potential of these materials, especially for higher temperature applications.

In all cases, there is a need to reduce overall material and processing costs for composite materials. However, increases in the volume of materials utilized will significantly help to improve this situation. But, for the volume to increase, there is a need to demonstrate the long-term durability of these materials to obtain increased customer acceptance. For composite material technology to develop, the number of trained engineering personnel must increase in all categories with specific needs in materials science, engineering mechanisms, and manufacturing engineering. Finally, the development of a nationally accepted materials data base is needed for full composite materials acceptance.

S/2589/MB0203/B

COMPOSITE MATERIALS



ADVANCEMENT INHIBITORS

- Material/processes are still evolving
- Questions of long-term durability slows customer acceptance
- Raw material and processing costs are high
- More skilled engineering resources are needed

REQUIRED DEVELOPMENTS

- High-temperature materials
- Refined structural analysis methods
- Unified technical data base
- Improved environmental durability
- Innovative, low-cost manufacturing methods
- Simplified repair methods

338-2378-8

Composite Materials Application Requirements

There are potential needs for composite materials for all categories of future aerospace systems. In many cases, if these systems are to become reality, it is critical that composite materials be developed and utilized. Not only will the individual categories of these materials be required, but also strong needs exist for hybrid systems, in many cases, performing multiple functions during operation.

COMPOSITE MATERIAL DEVELOPMENT APPLICATION REQUIREMENTS

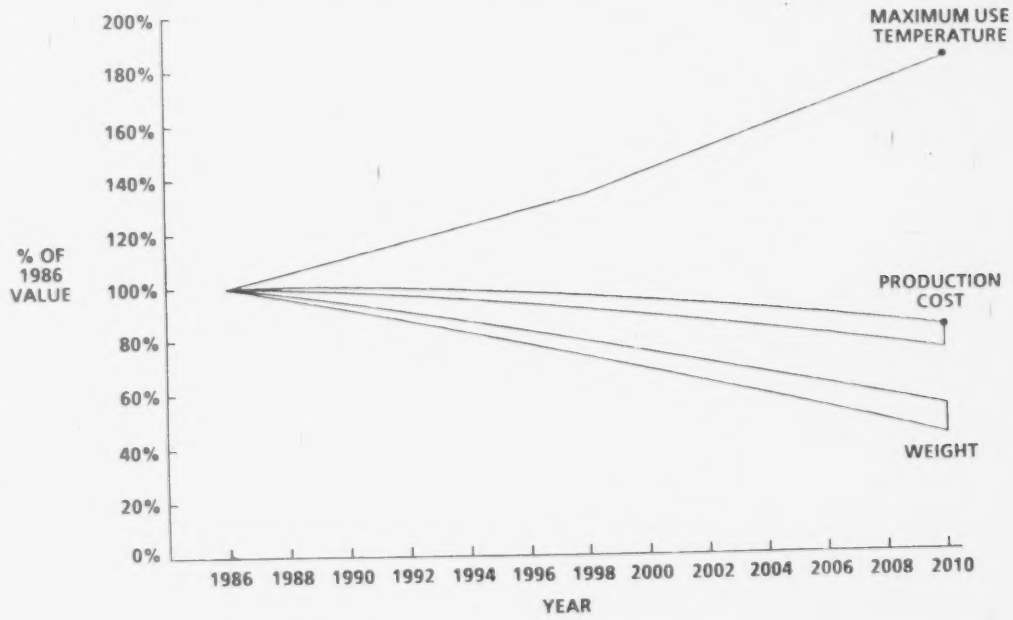
APPLICATION CATEGORY	APPLICABLE COMPOSITE					PROJECTED NEED DATE
	RMC	MMC	C/C	CMC	HYBRID	1990 1995 2000
TRANSPORT AIRCRAFT	••		•	•	•	
FIGHTER AIRCRAFT	••	•	•	•	••	
HYPERVELOCITY VEHICLES	••	••	••	••	••	
SPACECRAFT	••	•	•	•	••	
HELICOPTER	•				•	
MISSILES	••		•	•	••	
AIRCRAFT ENGINES	••	••	••	••	••	
SHIPS	••				••	
GROUND VEHICLES	••	•	•	•	•	
NUCLEAR REACTORS	•	•			•	
ARMAMENT/ARMOR	••	•			••	

•• = CRITICAL • = POTENTIAL

Advanced Composites Trends

Because of the breadth of materials technology covered under the Advanced Composites Roadmap, it is difficult to synopsize all of the key trends for the next 20 years in one chart. What is apparent is that all four of these classes of composite materials do offer significant potential for reduced structural weight and higher temperature capability. The trends shown for weight, cost, and temperature capability should be considered as qualitative measures of future improvements. For the less developed classes of advanced composites (i.e., carbon/carbon and ceramic matrix composites) these improvements would be much larger over the projected time frame. Similarly, with the increased resources, as recommended previously for each class of composites, these improvements would occur earlier than as shown.

ADVANCED COMPOSITES TRENDS



Composite Materials Benefits and Recommendations

Advanced composites offer several important benefits to aerospace systems. Of primary significance is the potential weight reductions (possible with advanced composites) which translates into a wide variety of performance benefits. Before composite materials' potential can be realized, further research and development is necessary focusing in the areas of performance, producibility and affordability. The implementation of the following recommendations on a concerted university, government and industry front will allow the aerospace industry to fully exploit this vital technology frontier.

RECOMMENDATIONS

- Accelerate development of a broad technology base with active government, industry and university support
- Demonstrate maintainability and cost effectiveness of advanced composites
- Pursue new and innovative material forms and processes to exploit potential of advanced composites
- Continue development of integrated design/analysis methods for effective and efficient fulfillment of system requirements
- Encourage open communication between DoD contractors to eliminate duplication of effort, lower development costs and spur technology development

MAJOR BENEFITS

The application of advanced composite materials represents the potential for major reductions in the weight of aerospace structure.

BENEFITS \ APPLICATION	PRIMARY VEHICLE STRUCTURE	ADVANCED PROPULSION SYSTEMS COMPONENTS	SPACE STRUCTURE	GROUND VEHICLES
SIGNIFICANT WEIGHT SAVINGS	X	X	X	X
HIGH-TEMPERATURE RESISTANCE	X	X		
REDUCED LIFE-CYCLE COST	X	X		X
IMPROVED SURVIVABILITY/ MAINTAINABILITY	X	X	X	X
CORROSION RESISTANCE	X	X	X	

Mr. FENTER. I believe it's important to note, though, that these road maps and these plans address only fundamental technology issues and they avoid encroaching on the proprietary rights of the individual companies, thus preserving the competitive motivation that drives all industrial research and development. And that's a fairly narrow line to have to walk, as you understand.

A vast array of applications for advanced composites results from the fact that they can be made stronger, more corrosion-resistant than steel. They can be made lighter than aluminum. They can be made extremely stiff or they can be made predictably compliant and tough, or they can be made very heat-resistant. In other words, you have the ability to tailor the properties of the material itself to your particular needs.

Not only are advanced composites an enabling technology for many just aerospace applications, but they're also important for—in the production of automobile components, biomedical products, sporting goods, many other products and I'm sure you're going to hear about many of them this afternoon.

By the year 2000, the projected composite market—composites market for just structural materials alone is estimated to be over $20 billion. I think last year, it was only $2 billion. This is a tremendous growth rate that people are projecting.

I think it's already been noted that composites also lessen U.S. reliance on foreign sources for many of the strategic materials required for use in corrosion-resistant steels and the super alloys, for example, in jet engines.

In addition, advanced composites are enabling—they're an enabling technology for some of the very newest concepts that are economically and strategically important to the U.S. The National Aerospace Plane, that's already been mentioned is a very good example of that sort of thing.

As a further example, I would mention that the future development of jet engines that use a carbon-carbon composite similar to that used on the nose cap of the Space Shuttle could result in an engine of the same size, but with twice the thrust and only 40 percent of the fuel consumption and it's a lighter engine, too—very dramatic implications. There's a program, by the way, been going on—a research program sponsored by DARPA and the Air Force for some five years now that does that as its objective.

Foreign competition in the field of composite materials continues to increase. I think we're all aware of that. Japan's announced plan to develop a supersonic commercial aircraft that would rely heavily on composite technology illustrates once again the Japanese strategy of targeting targets—markets, as well as their enabling technologies, all together.

Evidence of the erosion of our position is the dependence of U.S. manufacturers on foreign suppliers for the raw materials needed for many of these composites. I think it's ironic that the graphite fibers used in many advanced composites were first developed in the United States, but today a big majority of the graphite fibers used in this country are imported from Japan. But perhaps the over-riding irony is that these fibers are made from a petrochemical product, so the ultimate raw material is crude oil, of which Japan has none.

So our international competitors have shown themselves to be very adept at applying the results of our R&D to their new products. Unless we do a better job of applying advanced technology to our new products, we'll continue to be plagued with international competition that makes more timely use of our own—our own R&D.

In conclusion, I'd just like to state the AIA, the Aerospace Industries Association, is committed to the establishment of a national effort in advanced composites based on cooperation and consensus among industry, government and academia while retaining the benefits of competition in the marketplace.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Fenter follows:]

TESTIMONY OF FELIX FENTER

PRESIDENT MISSILES DIVISION

LTV CORPORATION

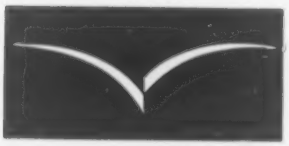
ON BEHALF OF

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

BEFORE THE

HOUSE SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS

JUNE 26, 1990



MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE:

MY NAME IS FELIX FENTER. I AM PRESIDENT, MISSILES DIVISION, MISSILES AND ELECTRONICS GROUP, OF LTV CORPORATION. TODAY, I REPRESENT THE AEROSPACE INDUSTRIES ASSOCIATION (AIA), WHERE I SERVE AS CHAIRMAN OF THE TECHNOLOGY AND OPERATIONS COUNCIL. AIA IS COMPOSED OF 54 OF THE NATION'S MAJOR MANUFACTURERS OF COMMERCIAL, MILITARY AND BUSINESS AIRCRAFT, HELICOPTERS, AIRCRAFT ENGINES, MISSILES, SPACECRAFTS, AND RELATED COMPONENTS.

THE AEROSPACE INDUSTRY IS GREATLY CONCERNED ABOUT THE CURRENT U.S. TECHNOLOGY BASE AND THE INDUSTRY'S FUTURE GLOBAL COMPETITIVENESS. AS A RESULT, AIA HAS INITIATED A NATIONAL COOPERATIVE EFFORT AMONG INDUSTRY, GOVERNMENT AND ACADEMIA CALLED "KEY TECHNOLOGIES FOR THE YEAR 2000". KEY TECHNOLOGIES IS DESIGNED TO INITIATE AND COORDINATE INDUSTRY EFFORTS IN THOSE TECHNOLOGIES THAT WILL PROVIDE A STRONGER AND HEALTHIER TECHNOLOGY BASE; ALLOWING INDUSTRY TO REMAIN A VIABLE COMPETITOR IN THE WORLD MARKETPLACE.

AIA'S KEY TECHNOLOGIES EFFORT ENCOMPASSES A THREE-PRONGED INITIATIVE:

1) THE AEROSPACE TECHNOLOGY POLICY FORUM, MADE UP OF HIGH-LEVEL POLICY LEADERS IN INDUSTRY, GOVERNMENT, AND ACADEMIA, FACILITATES THE IMPLEMENTATION OF TECHNOLOGY IN MATTERS OF NATIONAL POLICY. DR. BROMLEY IS A MEMBER OF OUR POLICY FORUM.

2) The National Center for Advanced Technologies (NCAT), an AIA-sponsored foundation, coordinates the Key Technologies daily operations, and leads the integration effort.

3) Technology teams, with broad participation by government and university experts, develop roadmaps and make recommendations regarding the direction of national technology development plans.

As the AIA sponsor of the Advanced Composites Roadmap, which is one of the ten AIA Key Technologies, I can state with confidence that the need for furthering advanced composites research was identified because of its high leverage and potential commercial and military applications.

AIA's Advanced Composites Roadmap is in close consonance with the Department of Defense Critical Technologies Plan and the Department of Commerce Emerging Technologies Report. This roadmap was released in May of 1989 outlining the tasks required to develop a national technology plan into the twenty-first century. A copy of the roadmap is included for the record. The Department of Defense is continuing to coordinate their efforts with AIA, thus enhancing both the AIA Key Technologies efforts and DoD Critical Technologies planning.

The National Research Council recently completed a study entitled, "Materials Science and Engineering for the 1990s". NRC recommendations include increased participation by the government in coordinating groups, and

SECTORS, INVOLVED IN, AND AFFECTED BY, MATERIALS SCIENCE AND ENGINEERING, WITH THE NATIONAL CRITICAL MATERIALS COUNCIL (NCMC) AS THE LEAD IMPLEMENTER. ADVANCED COMPOSITES, AS AN IMPORTANT MATERIALS SCIENCE, WOULD BENEFIT GREATLY FROM THIS RECOMMENDATION, BRINGING FORTH INCREASED ATTENTION AND FOCUS TO AN IMPORTANT RESEARCH SECTOR. AIA AND ITS ADVANCED COMPOSITES TEAM FIRMLY BELIEVE IN THE NRC'S GOAL AND STAND READY TO ASSIST WHERE NECESSARY.

THE TERM COMPOSITE MATERIALS REFERS TO A FAMILY OF MATERIALS MADE UP OF REINFORCEMENTS EMBEDDED IN DIFFERENT HOST OR MATRIX MATERIALS. RECENTLY DEVELOPED COMPOSITE MATERIALS HAVE IMPROVED TWO-FOLD IN STRENGTH, THEIR ROOTS LYING IN THE RESEARCH CONDUCTED IN THE AEROSPACE INDUSTRY OVER THE LAST QUARTER CENTURY. THE VAST ARRAY OF APPLICATIONS FOR COMPOSITES LIE IN THE FACT THAT THEY CAN BE MADE STRONGER AND MORE CORROSION RESISTANT THAN STEEL, LIGHTER THAN ALUMINUM, EXTREMELY STIFF OR PREDICTABLY COMPLIANT, TOUGH, AND HEAT RESISTANT. NOT ONLY ARE COMPOSITES AN ENABLING TECHNOLOGY FOR MANY MILITARY AND COMMERCIAL APPLICATIONS, THEY ARE ALSO VITAL IN THE PRODUCTION OF AUTOMOBILE COMPONENTS, BIOMEDICAL PRODUCTS, AND SPORTING GOODS.

IN 1989, ADVANCED COMPOSITES REPRESENTED AN APPROXIMATELY $2 BILLION DOLLAR INDUSTRY WITHIN THE U.S. BY THE YEAR 2000 THE PROJECTED GROWTH FOR MATERIALS AND STRUCTURES ALONE IS ESTIMATED TO GROW TO OVER $20 BILLION DOLLARS.

FROM A STRATEGIC STANDPOINT, COMPOSITES ARE NECESSARY IN PROVIDING HIGH LEVELS OF PERFORMANCE REQUIRED FOR NEW DEFENSE SYSTEMS AS WELL AS LIGHTER WEIGHTS FOR LAUNCH VEHICLES REQUIRED FOR FUTURE SPACE EXPLORATION. THESE

PERFORMANCE LEVELS, COUPLED WITH AFFORDABILITY AND RELIABILITY, GUARANTEE INCREASED UTILIZATION OF COMPOSITE HARDWARE. COMPOSITES CAN ALSO LESSEN U.S. RELIANCE ON FOREIGN SOURCES FOR STRATEGIC MATERIALS REQUIRED FOR USE IN CORROSION RESISTANT STEELS AND SUPERALLOYS.

ADVANCED COMPOSITES OF LONG TERM CRITICAL IMPORTANCE TO THE AEROSPACE INDUSTRY ARE KEYED TO SYSTEM APPLICATION AND REQUIREMENTS. CONTINUED DEVELOPMENT OF HIGH STIFFNESS, HIGH STRENGTH, TOUGH COMPOSITES ARE REQUIRED FOR EMERGING GENERATIONS OF BOTH COMMERCIAL AND MILITARY AIRCRAFT AND MISSILES. THEY ARE AN ENABLING TECHNOLOGY FOR SOME OF THE NEWEST CONCEPTS ECONOMICALLY AND STRATEGICALLY IMPORTANT TO THE U.S.- THE NATIONAL AEROSPACE PLANE BEING A PRIME EXAMPLE. AT THE HIGH TEMPERATURE END, DEVELOPMENT OF ENGINES USING A CARBON-CARBON COMPOSITE CAN POTENTIALLY RESULT IN DOUBLE THE THRUST AND FORTY PERCENT LESS FUEL CONSUMPTION.

FOREIGN COMPETITION IN THE FIELD OF COMPOSITE MATERIALS CONTINUES TO INCREASE. JAPAN AND THE EUROPEAN COMMUNITY HAVE ALREADY SHOWN MEASURED INCREASES IN MARKET SHARE IN MATERIALS AND HARDWARE. FURTHERMORE, JAPAN'S ANNOUNCED PLAN TO DEVELOP A SUPERFAST COMMERCIAL AIRCRAFT THAT WOULD RELY HEAVILY ON ADVANCES IN COMPOSITE TECHNOLOGY REITERATES THE JAPANESE PHILOSOPHY OF TARGETING MARKETS AND TECHNOLOGIES. THE U.S. CAN NO LONGER PROCRASTINATE. ACCORDING TO THE PREVIOUSLY MENTIONED NATIONAL RESEARCH COUNCIL REPORT, THE UNITED STATES IS ALREADY LAGGING BEHIND OTHER NATIONS IN APPLYING ADVANCED MATERIALS TO MANUFACTURING PROCESSES. EVIDENCE OF FURTHER EROSION IN THE MATERIALS FIELD IS THE DEPENDENCE OF U.S. MANUFACTURERS ON FOREIGN SUPPLIERS FOR RAW MATERIALS NEEDED FOR MANY COMPOSITES.

5

IF CURRENT TRENDS CONTINUE, THE UNITED STATES WILL NOT BE ABLE TO DEPEND ON ITS PRESENT RESEARCH AND DEVELOPMENT CAPABILITIES TO PROVIDE THIS NATION WITH SUPERIOR MILITARY AND COMMERCIAL PRODUCTS. FURTHERMORE, IF THERE IS NO EXISTING INFRASTRUCTURE IN THE U.S. FOR PRODUCTION OF ITS RESEARCH EFFORTS - THOSE EFFORTS WILL BE APPLIED TO SYSTEMS DEVELOPED BY OUR COMPETITORS.

AIA IS COMMITTED TO THE ESTABLISHMENT OF A NATIONAL EFFORT IN ADVANCED COMPOSITES BASED ON THE PRINCIPLES OF COOPERATION AND CONSENSUS AMONG INDUSTRY, GOVERNMENT AND ACADEMIA. IT IS OUR BELIEF THAT THE NATION MUST PLAN FOR THE FUTURE AS INDUSTRY'S ROLE EXPANDS TO AN INTERNATIONAL MARKETPLACE.

MR. CHAIRMAN, I THANK YOU FOR THE OPPORTUNITY TO APPEAR BEFORE YOUR SUBCOMMITTEE TODAY AND I AM PREPARED TO RESPOND TO ANY QUESTIONS.

Mr. TORRICELLI. Thank you, Mr. Fenter.

Mr. Gulcher, we do have three members here now who I know each want to ask questions at some length, so please try to economize on your time, if you could. Remember, your entire remarks will be in the record, but we would, however, like to hear your summary of them. So, Mr. Gulcher, please proceed.

Mr. GULCHER. I am Bob Gulcher. I am Vice President at Rockwell and I'm one of the program managers of the National Aerospace Plane. We are representing the whole team today, all the five participants, which is McDonnell, General Dynamics, ourselves, Rocketdyne and Pratt & Whitney.

I had the pleasure of briefing you on NASP out at Downey and I know Mr. Rohrabacher and Mr. McCurdy also are familiar with the National Aerospace Plane, but for those who aren't, it is a single-staged orbit, horizontal take-off accelerator to go on into orbit and it's fundamentally a technology development program which culminates, of course, with the X-30, which is an experimental airplane. It will provide the technological basis for future spacecraft and hypersonic aircraft.

One of the technologies is the high-temperature advanced materials, the lightweight materials necessary to make this happen. Aerospace planes have been looked at for many, many years and until these kinds of technologies can really come forth, it was not a very practical concept.

About three years ago, we recognized that the advanced materials were really not moving as fast as we would like. In fact, this was also expressed by a task force in Defense Science Board and others. Several of the industry members got together and suggested, actually, to the government that we form some sort of a consortium and let industry help, at least the government, develop these materials.

So we did that and it was primarily since all of the companies were working independently, you know, on certain kinds of materials, it made a lot of sense to focus those activities on those materials together. In other words, taking the competition of the materials out of the program and doing it in a consortium kind of way.

So we did that. We made a proposal to the government and they actually added several others. They included the whole team eventually and we set up, then, and received, actually, a contract from the government where we had associate contractor relationships between each of the five participants. It was set up where each company would be a lead. Rockwell had tialuminides; McDonnell had the metal-making composites; General Dynamics, the refractory composites; Rocketdyne, the—some of the high-conductivity composites and Pratt-Whitney, some of the more specific engine-related materials.

So that started and one of the things we assured was technology transfer between these by having each of us work on one another's. In other words, even though we had leads at one of the companies, we worked for one another and we did this on this associate contractor relationship.

We set up plans; we set up reviews; we developed, then, or improved on alloys. We did the processing. We did the fabrication and

we're now into the process of actually scaling those up. I think this fits a lot what Dr. Bromley was saying.

This country has a tremendous resource of material kind of developments in the science and various areas. It's really the synthesis and production that's necessary and that's really what this program was doing. It was taking this very large data base that the country has spent literally millions and millions of dollars on and took advantage of that and put it in such a way that you can make practical things.

This also, since the money increased significantly for materials, it also allowed suppliers to start investing in all because they started seeing a market for these kinds of materials show up and this became very important, too. We got a great amount of enthusiasm from a number of the suppliers doing that.

The program was managed by a—what we called a joint management team. We took the program managers of each of the lead companies. We selected one of them, in fact, it's Ned Newman, who's with us, and he was the one, then, that does kind of the day-by-day management of these various plans that have been agreed to and also agreed to by the government.

The government also participates. They do it in a rather broad direction, consulting, critiquing way and also utilizing some of the laboratories. One particular point was that all of the companies shared their IRAD at the beginning of this program. I think this is kind of a first in a way to actually see—I know on our own case, some 45 patents that we were showing to the other companies.

After a while, you really couldn't tell the people apart. They were working very closely together.

What have we accomplished? First, in the tialuminide areas, we have been able to—tialumide, by the way, is a intermetallic compound that's more ceramic-like and has high-temperature capabilities. Titanium is typically 8-, 900 degrees. Aluminum is typically 300, 350 degrees. By putting these together, you end up with an alloy that can be some 13-, 14-, 1500-degree kind of capability. We've been able to produce sandwich-type construction, which you see here, and we'll pass these around. Very light-weight, very efficient kind of structures. So this is now getting to these applications of actually producing things out of these very important alloys.

We produced and rolled, forged something like 16,000 pounds of this material which is probably 70 percent of all the titanium aluminide that's been produced in this country.

We also have worked in metal matrix composites. This is an example of that, of taking layers of foils, putting them together with silicone carbide in a composite form, like Mr. Fenter was talking about, and this now is a—has again a much higher temperature capability, about two times that of titanium itself, by actually alloying these, putting them together and producing them as a product.

We also worked carbon-carbon. Again, as Mr. Fenter was talking about, the Shuttle uses carbon-carbon, but it's in fairly thick laminates and all, and today, we can do these in very thin forms. This is typical of a beam that has been developed which has really about the fifth the weight of steel, very strong, very stiff, and also has the capability of some 2700 degrees when it's coated.

Mr. TORRICELLI. Mr. Gulcher, give us the comparison of the strength and heat resistance to steel, as you did with its weight.

Mr. GULCHER. I mentioned that 2700 degrees—titanium, as I say, is typically 900 degrees, 800, something like that, and this like 2700 degrees. Strength now is primarily one of more stiffness than strength. Again, it depends on a lot of the applications. The particular thing here, carbon-carbon is used primarily for heat shields. You will recall, on the Shuttle, they used ceramic-type tiles. This would now—could replace things of that sort and be much more reusable and a lot more practical from that standpoint.

Mr. TORRICELLI. If, in fact, you were redesigning the Shuttle today—

Mr. GULCHER. You would not use tiles. You would go to something either more in metals, depending again on the temperature, or carbon-carbon. Those things were not really available in those kind of capabilities or performance at the time the Shuttle—the Shuttle's really some 20-year-old technology.

We've also developed—

Mr. TORRICELLI. Interestingly, the Soviets, in their developing their own Shuttle, had they gone to a tile—

Mr. GULCHER. Yes, they had. In fact, I was over at the Paris Air Show—you could almost see the same pattern as the Shuttle. It very much is the same kind of thing.

I show you a comparison of weight. This is one of carbon-carbon fastener with a chunk of Columbia. Columbia is the things that were used like on X-15 and things of this sort for fasteners. Here's one made out of carbon-carbon and you can kind of feel the weight. It's about a fifth of the weight, actually. Of course, much, much thinner and about the same temperature capability.

Let me talk a little bit about the lessons we've learned out of this program, which maybe could form some benefit for the future as far as the government activities. In order to accelerate these developments, we feel the first thing that's extremely important is to identify the need and that's really what we did. You—the very well-defined requirements that we came up with which allows us, then, to get specific in the kind of developments that actually would go on and these are really applications-oriented. In other words, you're developing these materials and processes and all specifically for the kind of problems that you're seeing.

The second is, we feel it's important the program be focused. In other words, it has to have events, it has to have accomplishments identified and also identify when they'll be used. When you put that on, believe me, things happen, as opposed to kind of a more academic research environment that would not necessarily be that event-oriented.

The third item that we feel is the participation. There's a great amount of synergy possible in this country and we're seeing this every day. I think particularly now in the NASP program and certainly the materials have done this, where you get the involvement of many people, certainly from all the industry and their research labs, plus the government labs, the national labs, and all these various suppliers and also universities. So it is getting that rather large participation in a more synergistic way.

The fourth item we feel is very important is that of organization and management of the program. We did set up a master plan, as was talked about earlier. We do have now a common language so you can communicate from one to the other.

But we can also accommodate change. You know, when you go through things of these, say, you find that some things you ought to disband. You've got to decide, "No, I don't want to work on those any longer. I have other things that are more suitable," and be able to set it up and it's really dealing from something of being smarter, not saying, "Gee, I was not able to do something."

And then finally, you can make truly, then, a team of equals actually work together and that was extremely important.

The last item is one of partnership with the government and I think this is a very important, particularly—the government comes with a very large initial data base. They have so many things that they've developed over the years and they have provided, at least in our program, and I think in others, could, a rather broad direction. It isn't day-by-day, it isn't micromanaging or anything of that sort, but they provide a broad direction to the program. They critique it, they consult and they've helped us a great deal.

We can also benefit from their experience from other programs and they do bring that and it has been very valuable.

I think, also, it provides kind of the national data base for any future programs. Again, the starting of other things.

So finally, in the future, I believe it's been our experience in this consortium, which has also provided the basis for the national teaming that we're just starting. This synergy will continue, I believe, and probably be just as strong as we've had on the materials. We're proud of what we've done. We think it's been taking care of a need that's been needed for a long time. We think it'll be expanded now on the national team.

[The prepared statement of Mr. Gulcher follows:]

Testimony by

Robert H. Gulcher

Executive Steering Group Member

Vice-President Hypersonic Programs
Rockwell-International

and

Ned D. Newman

Joint Management Team Leader

Branch Chief-Technology
McDonnell-Douglas

On the
NASP Materials and
Structures Augmentation Program

Hearing on the
National Critical Materials Council

Before the
Subcommittee on Transportation, Aviation and Materials
Committee on Science, Space, and Technology
United States House of Representatives

June 26, 1990

34-733 0 - 90 - 3

The National Aerospace Plane (NASP) program challenges the American aerospace industry to attain a high level of technology for the 21st Century. In addition to the technological challenge, the national program concept demands innovation in management philosophies and implementation. The merging of aeronautics, materials, and space technologies into an aerospace vehicle provides the potential for an entirely new class of vehicles. This aerospace capability will ensure access to space with vehicles that can put payloads into orbit at significantly lower cost than today's systems and will greatly enhance the operational potential of high speed military and civil aircraft.

The technical challenges for the program are formidable but achievable. The management challenges of this great national effort are also formidable and achievable. Each of these challenges will require high levels of innovation, creativity and hard work.

This testimony explores the new concepts of cooperation, trust and teamwork between the NASP contractors, government, and industry as part of the NASP Materials and Structures Augmentation Program (NMASAP). It also indicates the advantage of this cooperation as the program has cut the development time needed for new materials in half.

One of the limits to achieving low cost space transportation and economical hypersonic cruise aircraft has been the unavailability of practical, low cost, high temperature, and low density structural materials. The NASP program, which is basically a technology development and advancement program, faced up to this need and initiated a very revolutionary approach to cooperatively develop these materials. Early in the program, the need to accelerate the development of the materials was recognized. At that time all of the participating companies and the various government labs were working somewhat independently. A proposal was made by several of the companies which was accepted and expanded by the government to collaborate in the materials development. A consortium was established based on the National Cooperative Research and Development Act of 1984 (Public Law 98-462) which allows the use of this approach by industry for conducting research and development work. The Joint Program Office (JPO) took the lead and modified existing NASP contracts with three airframe and two engine manufacturers to create a materials and structures augmentation program. The NMASAP consortium involves all five NASP contractors (General Dynamics, McDonnell Douglas, Pratt & Whitney, Rockwell-North American Aviation, and Rocketdyne). The basis of the program was an Associate Contractors Agreement which defined the principles of the program and was signed by all contractors. The Associate Contractors Agreement outlined the working relationships for the participants. The primary objective of the program was to accelerate the development of selected materials for the X-30 in a much shorter time than the typical 15 years generally necessary to qualify materials for use in manned aerospace vehicles.

Our confidence to proceed with this program was unusually high because much of the enabling composites materials and structures technology had been developed

over a 20-year period in the DoD core Science and Technology program. Over the period from 1970 to 1990 about 600 million dollars (Figure 1) has been expended by the DoD to build a technology base and establish a government, industry, and academia infrastructure which future programs could build upon. The NASP program has utilized this large technology base to initiate and focus the materials development.

The program approach is unique for companies in a competitive stage because it requires team participation, shared results, focused effort, and pooled resources. In other words, the **development** of materials was "taken out of competition" for the common benefit of the program. The **application** of the materials in the design of each contractor's configuration, however, remained competitive prior to the NASP teaming. During discussions at the NASP JPO, using inputs from the Wright Research and Development Center (WRDC) Materials Laboratory, we saw the opportunity to develop a program where the NASP contractors could work together as a team to bring key NASP materials to maturity.

As a participant in the NMASAP, each NASP contractor has a contract with the government for leading the development of a particular material, and the effort is focused toward risk reduction. General Dynamics is developing refractory composites; McDonnell Douglas, titanium metal matrix composites; North American Aircraft, titanium aluminide materials; Pratt & Whitney, high specific creep strength materials; and Rocketdyne, high-conductivity composites. Each company brings unique capabilities and strengths to the program. Technology transfer is assured since each contractor is also responsible for tasks in each of the material systems. Material requirements for the program key off the representative X-30 structural designs. Derived from these requirements are design allowables and processing and fabrication methods that will provide material scale-up. The five contracts total nearly $150 million and involve subcontractors from across the nation. This was a significant increase over the $17 million level of funding initially established early in the NASP program for material development. This focus on material and structural development established a potential market for these materials and lead to a significant amount of enthusiasm across the supplier community. Material developers have also contributed to the programs with a significant amount of IRAD funds.

Figure 2 shows how the program is structured. At the top level there is an executive steering group consisting of the program managers from each of the participating companies. Each company has assigned an individual to lead their team as a member of the joint management team. A leader of the Joint Management Team was selected by the Executive Steering Group to facilitate the coordination and integration of the NMASAP Team activities and implement the necessary decision making procedures. Additional key people are the program coordinators responsible for internal, corporate coordination. Each company contributed important resources by assigning individuals with essential strengths in each material system. Each company also shared significant proprietary developments and the use of specialized facilities.

The government management of the program is the JPO. The Interagency Programs Directorate is responsible for the NMASAP. The technical manager for the program and five government technical managers for each material system are located in the Wright Research and Development Center (WRDC) Materials Laboratory and maintain direct contact with the industry materials leaders. Figure 2 also illustrates the numerous government organizations that support the program. In addition to the management functions performed by the government, the various government research centers around the country are performing test and analysis of the material systems. They bring considerable expertise in such areas as powder technology and the effects of hydrogen on particular materials systems.

This integrated effort between the prime NASP contractors has been underway since March 1988 and has been quite successful, due to the leadership of the Joint Management Team (composed of managers from the five contractors); the guidance of the NASP Contractor Executive Steering Group; and the close working relationship between the team members, their subcontractors, and the NASP government team. The basis for the integrated effort is the framework outlined in the Associate Contractors Agreement. This agreement identifies how the executive steering group works, how the joint management team functions, how issues are resolved, and documents how task assignments are integrated. The management structure was established to allow for advice and counsel from each of the companies to be considered. Based on these inputs the Joint Management Team has the authority to make decisions on the program. Any unresolved issues are closed out by the executive steering group using recommendations from the Joint Management Team. One of the key characteristics and most unique aspects of the NMASAP was the agreement by the companies to share Independent Research and Development (IRAD) results that were applicable to the program. This information has included results from separate IRAD projects and material related patents. Test results from a considerable number of high temperature element tests were shared. The approach facilitates rapid technical advancements as new information was combined with each company's existing database.

Five key management principles illustrated in Figure 3, are used in the consortium help to bring this team together: **(1)** Identify the Specific **Needs**, **(2)** **Focus** the Research on the Needs, **(3)** Provide for the **Involvement** of Many Organizations and Companies **(4)** **Organize** the Work for Effective Accomplishment and Redirection and **(5)** Provide for a Strong **Partnership** with Government. Each of these principles bring a unique contribution to the program.

First, it is important to identify the specific **needs**. For the NMASAP the need was for high-temperature, light-weight materials that could be used for the X-30, and also to develop technology that is applicable to future aircraft and space applications, including NASP derived vehicles. These needs lead to the well-defined NMASAP requirements of high temperature and strength capability under NASP operating conditions. In previous materials development efforts, laboratory researchers have not generally worked with specific vehicle requirements in their development work. In our case, all the requirements are keyed to the experimental vehicle, the X-30, and were established at the beginning of the program. The requirements are

communicated throughout the system and impact structural design and establish the size and scale necessary for the X-30 applications. This structural scale-up data will be used to support the decision to build the X-30. The X-30 requirements give the NMASAP team a very clear vision of where we want to go and what's required.

Second, it is important to **focus** the research and development activities on the needs. The overall effort should follow a milestone approach that allows a variety of people at different sites to work towards a common goal with a clear understanding of the desired result. The milestone approach is important because we have a number of people with a variety of strengths working at five different contractor sites, and it ensures that everyone knows their task. Each individual must also clearly understand the milestone for their task and how it relates to the overall program. The milestones are keyed to technical products and hardware. Each contractor is responsible for leading a material system but is also responsible for completing specific tasks in each of the other material systems. Tasks are often worked in parallel which aggressively leads the material and process development to structural demonstration hardware. Our milestone approach allows researchers to understand where their data and work will be used. They get enthusiastic and understand where to take the next step in development.

Third, it is desirable to structure the program to maximize the **involvement** of the extensive resource base of people, data, and test facilities that are available in the U.S.. The industry, university, and government base has access to an extensive amount of available information that can be utilized to address the specific needs of the program. Tremendous national resources representing a wealth of materials information and experience are being drawn from the materials community, subcontractors, universities, government, and contractor facilities. We especially want to highlight the importance of NASA, Navy and Air Force centers which contribute their particular strengths and resources to the program. A significant partnership between government and industry is an integral part of the program. The consortium drew from an extensive amount of experience and data available from previous DoD sponsored programs which was applicable but had not been focused towards a single application. Many experienced individuals and companies who were involved with these programs became part of the NMASAP team. Many of these experts also have government directed tasks and assignments being conducted in the national laboratories. Over 60% of the work in the NMASAP is subcontracted by the five prime contractors and there is large participation by industry, government and universities. Figure 4 is a map of subcontractors that support the program and illustrates the breadth of our work. NASP management principles have been carried over to the subcontractors allowing them to understand how their task will complete a program milestone and contribute to the overall success of this program. The significant use of national resources has given those involved a sense of opportunity and a chance to make a breakthrough. Through their innovations our people have demonstrated a wide range of talent and expertise and enjoy being part of a high performance team. They can be recognized as a contributor to the overall program instead of just being recognized for their individual accomplishments in the lab.

Fourth, the work needs to be **organized** to cover the broad spectrum of activities and also provide a master plan and common language for communication. The plan should envelope the efforts leading from material development and analysis to fabrication, test, and scale-up. Flexibility should be included to allow for parallel path development and revisions to be incorporated. The organization needs to be able to accommodate these changes in step with the decision making process established for the program. The organization should be established to facilitate the decision-making process and encourage creativity and participation and the result in clear direction. Problem resolution and the steps necessary to resolve issues need to be established early in the program. Using the X-30 as a single focal point has allowed us to pull all these resources together and integrate and focus the efforts. The experience available across the technical community, coming from a broad spectrum of existing data and programs, has allowed us to essentially consider a vast number of potential material candidates, processes, fabrication approaches, and test methods for further work in the program. Based on lessons learned from other programs, approaches that might be applicable to the X-30 were evaluated. The strength of the team's experience and knowledge have enabled quick assessment of potential material candidates prior to committing significant resources. This approach has allowed us to pursue various technical approaches in parallel paths and downselect quickly. Experience has shown the need to document plans, commitments, and obligations for all of the participants. Therefore, each job is defined in a Master Plan and Control Document which identifies the material system, the task, the contractor assigned to the task, and how the job relates to the schedule. We have established a common language throughout the consortium, a Work Breakdown Structure (WBS), which relates how the tasks fit together. Experience has also shown that a common language is critical because it allows five different individuals from five different companies to work on complementary tasks and bring the technological developments to fruition at the same time. Our approach to organization has allowed a great variety of individuals, who sometimes have differences of opinions, to work together constructively.

Lastly, it is important to establish a **partnership** with government as an integral part of the effort. The government team has been involved in several key areas. These include establishing the initial database, furnishing broad direction, encouraging involvement of various organizations, offering critique and consulting advise, providing information and data from on-going parallel developments, and assembling data from other programs that may be applicable. The Government involvement also ensures that the database can be useful for other programs so that the benefit can be multiplied throughout DoD and also to the potential commercial users.

This NMASAP team has already made the program a success by accomplishing many industry firsts as well as providing benefits and spin-offs in other areas. We've come a long way and are only two years into the program. Achievements include the development of alloy and fiber materials, screening and selection of candidate materials, analytical modeling, fabrication of subcomponents, characterization and development of preliminary design allowables, and fabrication of large scale-up components. Refractory composite development has included both

carbon-carbon and ceramic matrix composites. Designs using carbon-carbon or ceramic matrix composites for primary structure or thermal protection keep structural weight of large components relatively low. Carbon-carbon consists of carbon fiber in a carbon matrix, while ceramic composites consist of carbide, oxide, or nitride matrices with ceramic or carbon fiber reinforcements. In the program coated carbon-carbon specimens have been successfully tested in a NASP environment. Large carbon-carbon structural panels have been fabricated and coated. Composite materials using a titanium matrix reinforced by high temperature silicon carbide fibers retain stiffness and strength at elevated temperature. Work on titanium matrix composites for NASP includes alloy development and characterization, fiber development, processing, structural fabrication, and large scale tests. Oxidation resistant beta titanium has been produced and large ingots have been forged and rolled. Rule of mixture properties have been achieved and low interstitial composites have been made. Large titanium matrix composite structures have been fabricated and testing is underway. Development of monolithic titanium aluminide alloys is underway to yield structural metals with low density and high temperature strength. Work is focused on developing alloys with the required ductility and toughness and on necessary rolling technology. Large quantities of alpha-two titanium aluminide alloy sheet have been produced and gamma titanium aluminide alloy sheet has been rolled successfully. The X-30 will make extensive use of active cooling for leading edges, engine combustion chamber walls, and other high heat flux surfaces. Work on high specific creep strength materials is aimed at development of composites for these areas which will meet engine heat flux requirements in structural panels cooled by hydrogen. A variety of fibers needed for high temperature engine composites are under development, have been produced, and testing is underway. Materials are in development that have both high thermal conductivity and structural efficiency at elevated temperature. Copper matrix composites using high modulus graphite fiber for good structural and thermodynamic properties and beryllium which combines the attractive properties of low density, high stiffness, and good thermal conductivity are included in this effort. Work is focused on ways to increase structural efficiency at elevated temperatures. Ingots made of copper microcomposites have been scaled up and graphite-copper components have been fabricated. Powder-making facilities for beryllium are in place and operational. Materials produced show promising results.

Another major benefit has been the rapid technology transfer accomplished within the team and throughout the industry. These achievements have been shared with numerous related DoD programs and technical societies. This has been accomplished through shared IRAD, shared test results, and workshops and has been enhanced by team participation, flexible planning, and pooled resources. Examples of technology transfer include presentations at meetings sponsored by the American Ceramics Society, American Institute of Aeronautics and Astronautics, American Society of Metals, DoD Metal Matrix Composite conference, and the Society of American Materials and Processing Engineers. These NMASAP achievements have laid the ground work for material spin-offs which may be applicable to the medical, automotive, and commercial aircraft industries. These applications will take advantage of the lightweight, high temperature strength properties offered by these materials. Future spin-offs may also contribute to advances in the chemical

processing and the traditional heavy industries by allowing higher processing temperatures. These applications are important and will be needed to allow the U.S. to be competitive in the world market place. The Japanese, for example, have applied titanium–aluminide materials to turbocharger impellers. The French have developed and flight tested refractory composite engine components on fighter aircraft.

Using the "lessons-learned" from the NMASAP several recommendations for a national materials program can be identified. Although the NMASAP is benefiting the limited area of high temperature, low density materials the approach could be a model for other programs. In summary, the new approach needs to:

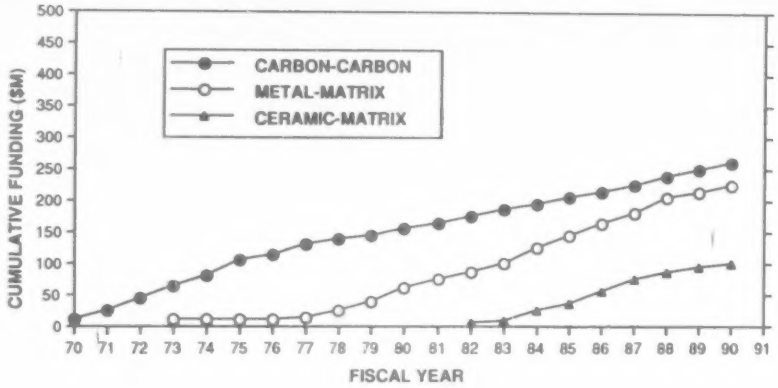
1. Identify specific **needs**
2. **Focus** the research on the needs
3. Provide for the **involvement** of many organizations and companies
4. **Organize** the work for effective accomplishment and redirection
5. Provide for a strong **partnership** with the Government.

In conclusion, the approach used by the NMASAP has led to significant achievements in a dramatically reduced amount of time compared to typical material development. The results have benefited the U.S. technical community by increasing the overall knowledge base and by sharing the technical progress with other programs and applications. The international competition in materials development requires a different approach than that traditionally used in the U.S. materials industry. Foreign competition is strong, and countries such as Japan, France, West Germany and the Soviet Union are pursuing their own versions of an aerospace plane. We must also commit and manage our national resources properly if we are to achieve the NASP goals and maintain our nation's pre-eminence in aerospace. The advancement of high temperature low density structural materials will help to assure the competitiveness of the U.S. in developing hypersonic vehicles representing the next generation of Aerospace Systems.

34-733 0 - 90 - 4

SCIENCE AND TECHNOLOGY COMPOSITE MATERIALS AND STRUCTURES TRANSITIONS TO NATIONAL AEROSPACE PLANE (NASP) PROGRAM

(ARMY + NAVY + AIR FORCE + DARPA)



NASP CONSORTIUM

- TITANIUM ALUMINIDE
- TITANIUM ALUMINIDE COMPOSITES
- HIGH SPECIFIC CREEP STRENGTH MATERIALS
- REFRACTORY COMPOSITES
- HIGH CONDUCTIVITY COMPOSITES

Figure 1.

NMASAP Organization Supports Specific Task Assignments For Each Material System

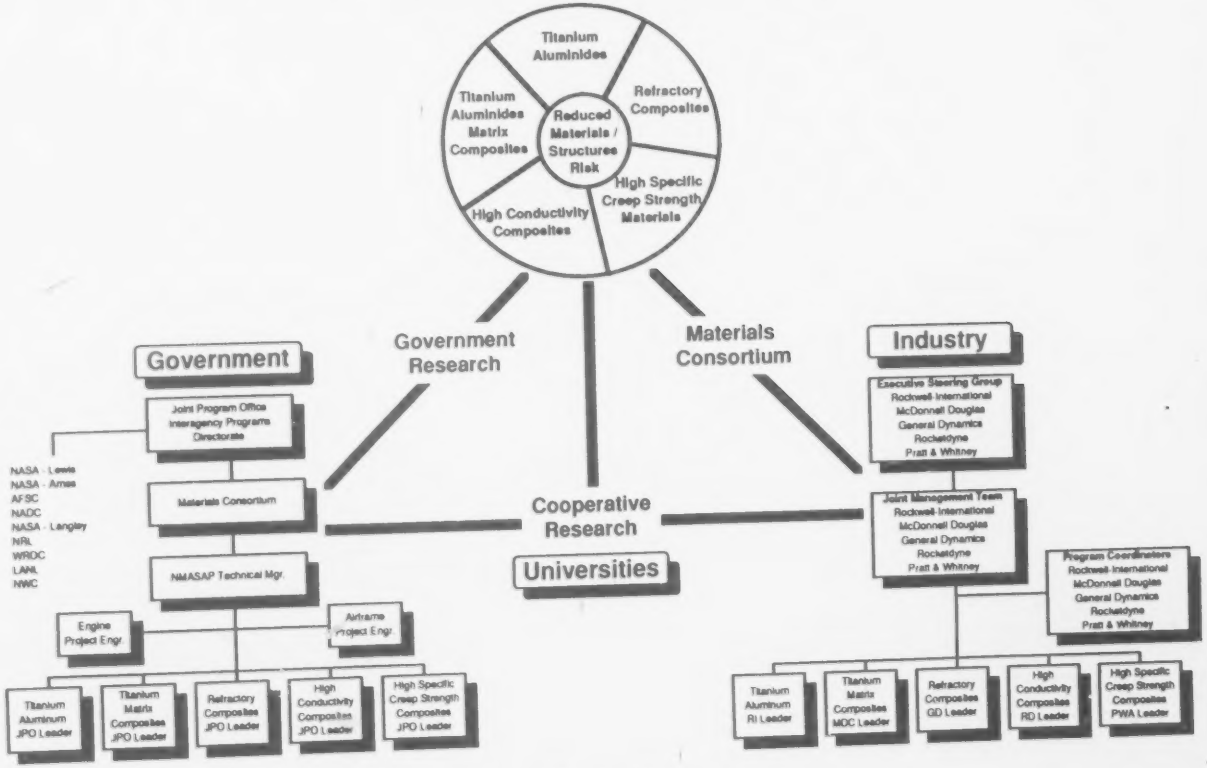


Figure 2.

The NASP Materials ASAP Is Focused Toward Risk Reduction

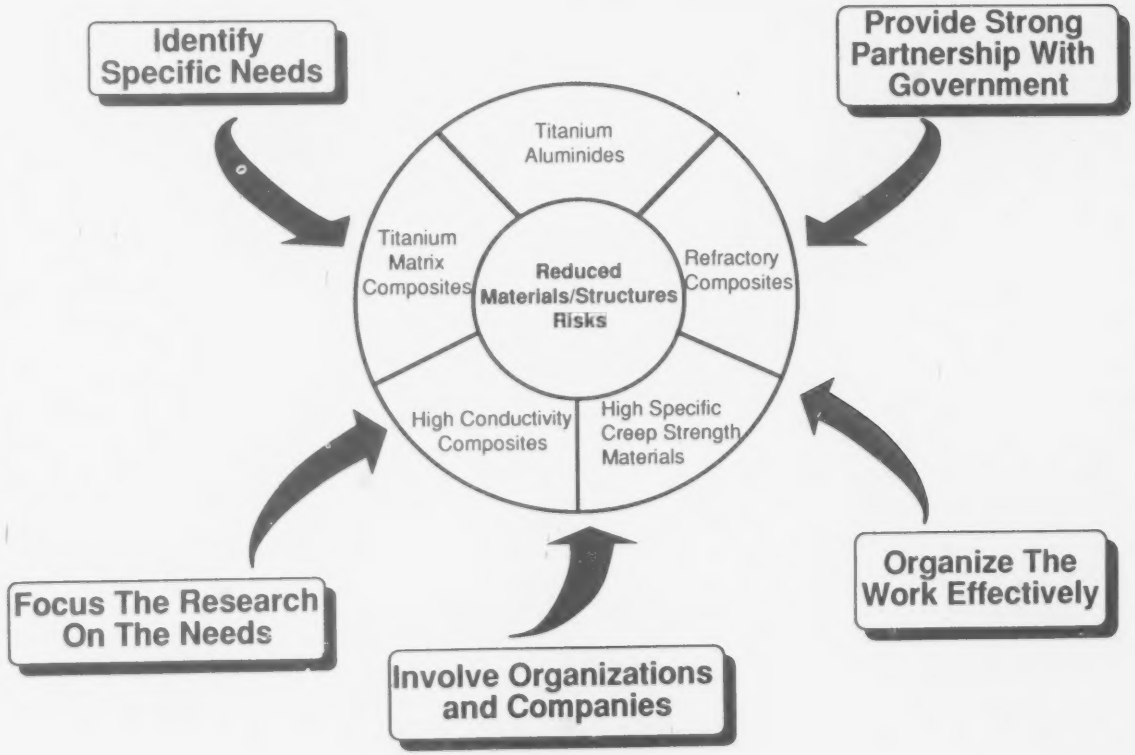


Figure 3.

NASP Materials ASAP Has Heavy Subcontractor Involvement

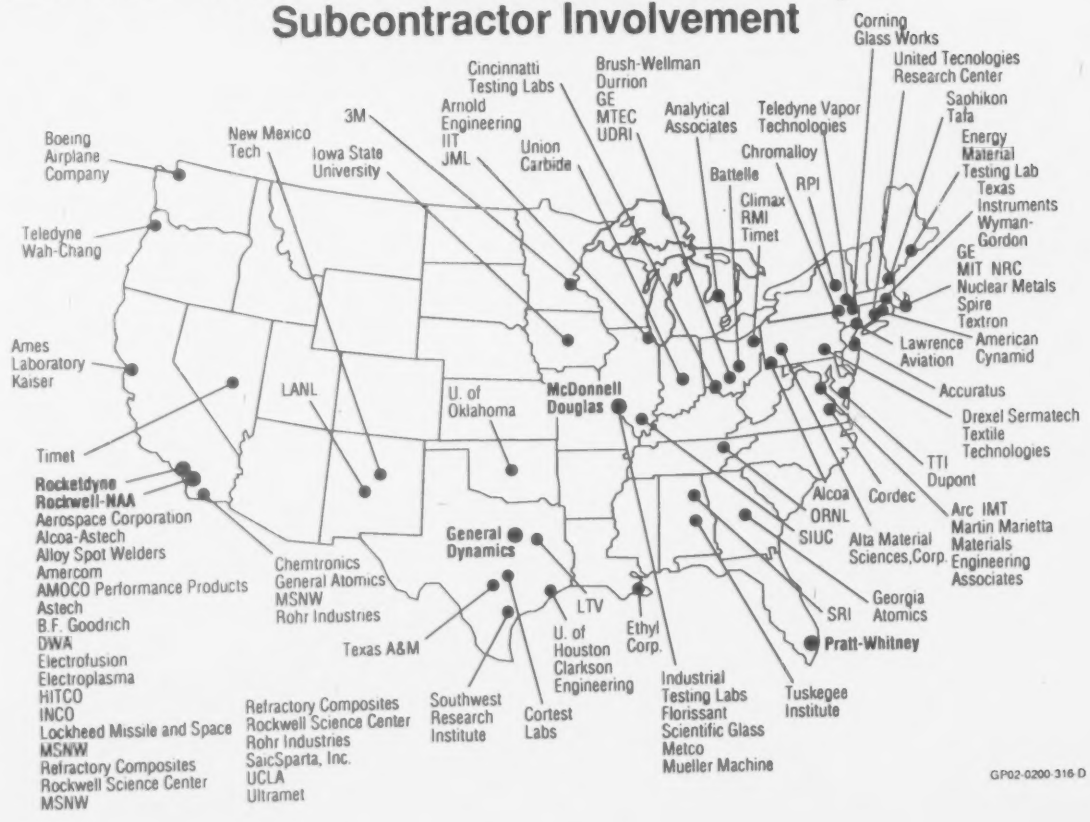


Figure 4

Mr. TORRICELLI. Thank you, Mr. Gulcher.

Mr. Dieck, you have the last word.

Mr. DIECK. Yes, my name is Ronald Dieck, and I represent Dow Corning Wright, which is a wholly owned subsidiary of Dow Corning Corporation, and I feel, being a part of the medical business, I might bring a different perspective to the use of materials and, as a prop, I brought my friend along back here, my skeleton, to make a point.

Mr. TORRICELLI. I'm glad you explained what that was, Mr. Dieck. It's like election day in Jersey City.

[Laughter.]

Mr. DIECK. We're not sure where he come from.

And the point is this, the human body, the skeletal part, is basically the most ideal structural material you can come up with and it's covered with yet another advanced material called skin. And as far as delivering medical care to the populace, advanced materials, I think, offer a really critical advantage to us here.

In fact, today, every day, thousands of Americans benefit from advanced materials and medical devices. Now, most of those advanced materials were developed out of the aerospace business and then found their way into the medical arena, and I want to stress, found their way into, because I think this is a critical issue that I'll follow up on in a few moments.

I want to leave you with really three things as far as the impact of advanced materials in the medical business, and they're not all economic. One of them is very social to begin with and very personal and that has to do with basically the pain and suffering that's associated with disease states.

And today, hundreds of thousands of individuals who suffer from arthritis, suffer from heart defects, benefit from devices that have evolved out of these advanced materials. As a side to that, there is the economic benefit and that is the elimination of the strain on the family and also the elimination of the care, much that's funded and supported by the government, that goes into taking care of individuals who can no longer work and can no longer function effectively in society.

And the third area is that of industry. The medical device industry today is a healthy 50- to $60 billion a year business and growing at a rate of over 20 percent a year, and I might add, of that business, almost 50 percent of it is sold off-shore, so we're helping a little bit with the balance of trade as well.

To give you some examples of that—the economic and the social impact, I've got five brief examples of how medical devices might work. The first is the use of an advanced material silicones which was first developed during World War II and has since been modified and evolved into many uses in the aerospace industry, fuel hoses, gaskets, caulking materials are just a few examples.

And the medical applications that go with that, the first is oftentimes, as a result of burns, tremendous trauma to the skin occurs and replacing the skin itself is—is key, but the next step is to deal with the scar that results from the burn itself, in particular on the hand, or across any joint. A heavy scar means you cannot—you can no longer move that joint.

And the first product is a silicone material and I have some graphics here in the background. Basically, it's a silicone gel material, the exact same composition of certain gaskets that are currently sold on the market right now. And I have a before and after on the next graphic back there. This is an example of a third-degree burn, which had scarred over on the left-hand side. On the right-hand side, by simply being able to use this gel material and isolate it from the outside atmosphere, the scarring and a lot of the discoloration was removed. This individual's able to go back to work because he can use his hand once again.

Mr. McCURDY. Is that a permanent fixture?

Mr. DIECK. Yes, it is. How this works is it takes about six weeks of constant application with a Ace bandage as an example. They remove it and then the patient is ready to go back to work.

The second example, also using silicones, is in a device called a tissue expander.

Mr. TORRICELLI. Your answer to the question is it permanent, you apply it for six weeks and then the benefit is permanent. You don't continue using that—

Mr. DIECK. The benefit is permanent, correct. It is not a permanent device.

The next device is what is called a tissue expander and this is to deal with trauma, for instance, automobile accidents, where large amounts of skin have been removed and it would cause—the only way to treat it in the past has been through grafting and grafting also results in—in scars.

An example of how the tissue expanders work, I have outlined here in the graphic—as a matter of fact, this represents—many of you might be aware of Jessica McClure, the little girl that fell in the well in Texas, what, two years ago now, and she's kind of our star patient, and the tissue expander, very simply, is implanted around where the defect is. In her case, it was in the middle of her forehead, about a two-inch-across defect, and over a period of four weeks, the tissue expander is inflated with saline and your skin has a very unique feature, it grows very quickly, it stretches and at the end of our weeks, the expanders can be removed and you have excess skin. In her case, that excess skin, which is very healthy and normal tissue, was simply moved over the defect and there she is on the bottom there, about four weeks after the procedure was finished.

In the final area in silicones that I wanted to mentioned, has to do with rheumatoid arthritis. Rheumatoid arthritis just in the U.S. alone, impacts 2.1 million people and I think there's probably not one of in the room here who do not know of an individual who has fingers that bend at right angles or have completely fused together and they can no longer use their hands.

About 10 years ago now, silicones were first looked at in the area of artificial joints for the hand, artificial finger joints, and the devices look something like this, very simple, and what the surgeon is able to do is to replace the key joints in the hand which allow for mobility so you no longer have crooked fingers; you no longer have fused joints; you're able to grab things, to write, and I might add, rheumatoid arthritis is not necessarily an older person's disease.

It's a young person's disease. This means putting people back to work again.

Mr. McCURDY. Can you use that for spinal, for replacing cartilage and discs? Has that—

Mr. DIECK. I don't think that that—that application has been looked at yet.

The second area I'd like to talk about is composites, strategic metals and ceramics and their use in medical applications. And there are two areas here that I'd like to highlight. The first is the treatment of hip disease. This is typically arthritis again, but can also be caused by automobile accidents and other types of trauma.

The current state of the art devices depend very heavily upon titanium, titanium being a very common structural member in most aerospace applications. And I give you this example. This is an artificial hip. The device is used to—is used to replace basically the top of your femur, your thigh bone. By using titanium, rather than stainless steel or a cobalt chrome alloy, we have been able to develop a modular hip device, so no longer do we have to cut away a lot of the center part of the bone to accommodate the shape of the device because the metal won't bend. We've been able to adapt the device to meet the geometry of the bone itself. So what you have here is literally a device which can be turned at any angle, turned at any angle, to meet the specific geometry of the bone. This is only because it's titanium.

Now, I mentioned earlier about technologies finding their way to the medical arena, and before going on to my last example, I'd like to talk a little bit about the future of hips. This is an example of the new composite materials that we're looking at in the medical arena. This is carbon-carbon. This particular carbon-carbon, and the process by which it's made, comes from a French company. It turns out that this is a strategic material here in the U.S., totally sourced by that one French company. I think from a long-term standpoint in our business, in the medical business, I have grave concerns about where other advanced materials are coming and how can I have access to those when they're not coming from the United States.

The final device is the artificial knee, which is also—which is also developed because of arthritis and because of trauma to the knee, and basically the device works like this. There are two major components. The first is a cobalt chrome cap that goes on your thigh bone and the second is a titanium platform which goes basically on the femur—on the tibia, it's called, and then the cushioning is a high-density polyethylene material.

In the U.S. today, 120,000 procedures are done per year. And I might stress again that this has a high percentage of young patients, patients in their 40s and 50s. They have many years of work left. The alternative to this, before the development of total knees, was fusion. You could no longer bend your knee.

Where the future is for the knee also rests in advanced materials, and I have an example here today of—actually the first prototype of our ceramic knee. I might add, once again, that the materials for this come from off-shore. This happens to be a Japanese vendor.

So I guess the bottom-line message that I'd like to leave the committee with, if I could, is advanced materials are key to continuing evolution of the medical device business. And the medical device business, in order to remain competitive, has got to have access to those advanced materials. And I would encourage some type of policy to be developed in order to enhance the development of materials in the United States—that's basic research—their understanding—the understanding of those materials from a biocompatability standpoint, as well as a mechanical standpoint, and a better way to inform those satellite industries so they can benefit in a faster fashion from those new materials.

Thank you.

[The prepared statement of Mr. Dieck follows:]

TESTIMONY SUBMITTED TO

THE UNITED STATES HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS

JUNE 26, 1990

BY

RONALD L. DIECK

VICE PRESIDENT, RESEARCH AND DEVELOPMENT

DOW CORNING WRIGHT

TESTIMONY SUBMITTED TO
THE UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS

Mr. Chairman,

I am Ronald D..eck, Vice President of Research and Development for Dow Corning Wright. Thank you for this opportunity to testify on some of the aspects of advanced materials. The purpose of my testimony today is to illustrate the significance ofmaterials to society, highlighting the use of advancedmaterials in health care. The balance of my testimony focuses on broader material issues including the need to increase the amount of cooperative research and development (R & D), the importance of the National Research Council's report entitled "Material Science and Engineering for the 1990s," the need to support civilian R & D, a proposal to use loans in place of R & D contracts, and the need to improve the support of that area of product and process development beyond research.

Dow Corning Wright is a wholly owned subsidiary of the Dow Corning Corporation. It researches, develops and manufactures the corporation's health care products. The next few pages describe typical products and uses.

Every day many thousands of Americans are impacted by the availability of advanced materials to the health care industry. Originally developed for aeronautical and military applications, those high performance materials are capable of playing critical roles as medical devices. Typically, these materials take several years before they are available to the medical community. They are then designed into critical devices such as artificial heart valves and blood vessels, hip, knee and finger joints and less invasive surgerical devices.

The economic impact of new materials on the health care system of the nation is multi-fold. Development of heart valves and vascular grafts from materials originally directed at the aerospace industry has prolonged life for hundreds of thousands of people in the United States. Many individuals who would have faced imminent death just twenty-five years ago, now have a high probability of leading active and productive lives. Artificial joints which have developed out of advanced materials, such as titanuim, are a second example of how new materials can dramatically affect the nation's health care system.

Every year over three hundred thousand people have a diseased knee or hip replaced with an artificial joint. These are individuals who would have been confined to a wheelchair and can now return to normal lives. The economic impact from a health care delivery saving plus improvement in the individual's productivity is significant. Finally, less invasive catheter systems which employ high performance plastic materials are having a significant impact on medical costs. Using small plastic tubes with a variety of metal and plastic tips can allow the physician to perform surgical procedures without a major operation. This limits hospital costs and recovery times as well as minimizing trauma to the patient.

Advanced biomedical materials have a secondary impact on the general economy of the nation. The medical device industry has grown into a multi-billion dollar a year business. Some segments have experienced growth at over 20% per year. This has resulted in the creation of thousands of new jobs and in certain areas has rivaled the success of the electronics industry. The United States is dominant force in the medical device industry with many companies exporting over 50% of their products.

While the United States has enjoyed a dominant global position in the medical device arena, recent years have shown some erosion of this position. Medical device companies in Europe have begun to capitalize on the development of new composite materials. Japan has been heavily involved with the use of new-ceramic materials in medical applications. Without access to new and comparable materials, domestic companies will be at a distinct disadvantage by the turn of the century.

The federal government could play a pivotal role in helping the medical device industry maintain its competitive edge. The key is the rapid access to new materials and a focused program to encourage the continued development of advanced materials. Funding of basic materials research plus encouraging research to understand the biocompatibility of materials through such agencies as the National Institutes of Health, would assure a continued flow of new materials to this rapid growth industry. It would allow some medical companies to compete on an equal footing while delivering new and innovative health care products to the nation.

Some specific examples of advanced materials in medical device applications might better reflect their impact on the individual patient and the health care industry as a whole. Silicones are high performance plastics, rubbers and fluids which were first introduced in the United States for aviation applications during World War II. Over the years this class of advanced materials has been developed and refined as commonly found in such aerospace applications as

fuel tank sealants, gaskets, O-rings, lubricants, and electrical/electronic insulation. Silicones were first used in medical applications over twenty years ago. Today, improved formulations of this material are still being evaluated in a wide variety of medical devices.

Damage to skin can often cause emotional and psychological trauma as well as result in loss of productivity. It is estimated in the United States over 18,000 people annually suffer because of automobile accidents, removal of tumors or other trauma to the body. Often times individuals are confined to bed and cannot work for months because large wounds heal very slowly. The resulting scars are often unsightly and cause pain. Because of the development of advanced silicone materials, several American companies have developed devices to help the skin rapidly repair itself and allows the patient to return to a normal life. These devices are called tissue expanders and are implanted under normal skin where they are blown up like balloons over a several week period. This causes healthy skin to form which can be surgically moved to the damaged site. It minimizes scars and aids in the healing process and allows the individual to rapidly return to a normal lifestyle. Over 30,000 of these devices are manufactured annually in the United States.

Another use of advanced silicone materials centers around the treatment of finger joints which have been damaged through trauma or disease. Most people are aware of the crippling affect of rheumatoid arthritis on the human body. The hand is particularly susceptible to this debilitating disease where most patients lose the use of both hands because the joints "fuse" together. It is estimated that 2.1 million individuals suffer from this disease in the United States. By employing a unique silicone elastomer or rubber medical device, companies have been able to design a device that mimics the finger joints. Every year over 15,000 hands are brought back to service in this country alone.

Titanium alloys, composites and ceramics all have their base roots in the aerospace industry. These materials are developed as light weight structural materials which offer strength with improved fuel efficiency. Many of these materials have been developed in the last ten years and are already found in applications such as brakes for aircraft, wing members, rocket nozzles and engine parts. Recently, these advanced materials have been used in new medical device applications in the orthopedic and cardiovascular fields.

Every year over 300,000 people in the United States have a knee or a hip replaced with a total joint prosthetic. Normally, this is because of trauma to the joint or osteo-

arthritis. Before artificial hip and knee joints this painful condition resulted in active individuals becoming slowly limited in their activities. Eventually many of them were confined to wheelchairs. Today these people can return to work in approximately two months from the time of surgery. As advanced materials such as ceramics and composites enter this field, recovery times will be improved and the overall performance of the medical device will go up. This will allow future patients to live more active lives with a high quality of life. In the United States, these devices represent a combined business of over 1 billion dollars annually. Advanced materials are key to the continued development of new medical devices and the dynamic medical device business. This is only one example of the impact of materials on the national economy. Returning people to work, lowering health care costs, creating new jobs and businesses, and a favorable balance of trade are just a few of the positive factors. In order to continue to capitalize on the dominance of United States health care companies, it is critical that the flow of new materials be improved. A national policy to assure that basic research continues and that information flows rapidly would keep us competitive as a nation.

National policy should encourage expanded cooperation amongst industry, national laboratories and academia. The public receives the benefits of new technology through new products manufactured by industry. The new and improved products would not be possible without the solving of difficult material technical problems. More productive solutions would be realized if more of the skills of our people in our national laboratories and universities were applied to these problems. Not applied separately, but applied in a cooperative way, focused on a common goal of new product introduction to the public. National policy should encourage expanded cooperation amongst industry, national laboratories and academia.

I congratulate the Congress on the steps they have taken to facilitate these joint working relationships. The Stevenson Wydler Act and subsequent laws have promoted technology transfer between industry and the national laboratories. We, at Dow Corning, recognize the potential benefits and are currently forming four cooperative R & D agreements (CRADA's) with national laboratories.

The recent National Research Council report entitled "Material Science for the 1990's, Maintaining Competitiveness in the Age of Materials" did an excellent job of identifying our materials situation and made appropriate recommendations for action. Many of us in industry, academia, and the national laboratories are involved in helping implement these recommendations. Regional workshops are being conducted toward this end, at

the request of Dr. Allan Bromley, the President's science advisor.

The congress's previous actions to promote industry - national laboratory technology transfer and the National Research Council's report have helped us form a vision of the ideal, yet possible, way to remove research ideas out of the laboratory and into the hands of the public.

A VISION OF THE FUTURE

A well known company commercializes a new line of material products through collaboration with a university and a national laboratory. The company is part of a vertical consortia, i.e., consisting of one or more suppliers and customers.

The university performed studies and generated data on fundamental process science. They worked with industry to develop an experimental plan leading to a viable process meeting economic and customer requirements. The university receives royalties based on patents received and utilized in products.

The national laboratory provided equipment, process models, sensor developments, instrumentation and on-line real time process controls. The national laboratory chosen was based on equipment and expertise available. On site industry personnel provided customer and economic requirements.

The guiding philosophy of this collaboration was to use existing capabilities that are required to meet the end use requirements. Team members were chosen and employed because of their superior capabilities to meet specific technical needs.

Funds and/or manpower and other resources were provided by the industry consortia, industry association, federal government and the university. The federal government provided loans which were repayable at no interest from the product's profit.

The federal government provided an environment conducive to the success of this team and its goals. This includes a reasonable cost of capital through debt reduction, tax loan and national savings incentives. The funds they provided for this team are from a new federal initiative to

improve the international competitiveness of the materials industry. This initiative focuses on critical technologies.

The company produced the product based on ownership of patents, proprietary rights to data and protection from the Freedom of Information Act. The product is sold internationally.

I hope you agree that we (government, academia,industry) should do all we can to realize this vision. It would not only create jobs and maintain our competitiveness, but it would also more productively use our national resources. We at Dow Corning, will continue to increase our joint work with national laboratories and universities. We ask you to continue to do what you can to promote these relationships and create a conducive environment for this activity. As mentioned in the vision, reduced cost of capital through debt reduction, tax and national saving incentives are required. Also mentioned in the vision are loans for dual use or civilian use technology. We believe economies sill be realized if loans are issued to support civilian R & D instead of the usual R & D contracts. These loans would be repaid from the sale of the products resulting from the research. They carry 0% interest and are forgiven if the research does not result in a viable product.

Materials research, development and manufacture for military use is significantly diffeent that for civilian use. the significant difference is that the federal government controls the military market. the greter uncertainty of the military market and higher risk associated with that uncertainty adds to the cost of providing materials to this market. This cost or risk is managed by asking the military to support a larger share of material R & D, process development, process scale up, and product demonstrations.

Military materials research programs exist although or preoccupation with "hardware" orientation often results in less than adequate funding. When funds exist the military utilizes their very competent materials people to contract for materials research. Support for areas beyond research, i.e.,product development, process development, process scale up, aand product demonstrations are not as evident. support in these areas need to be improved if basically commercial industries, like the materials industry, are to be enticed to work on military products. As shown earlier, many materials invented for military applications spin off into civilian use. This gives added importance to military requirements.

One other characteristic of military markets discourages commercial companies from participating. On sole source procurements, the rules require pricing based on cost. since materials do not fit the government costing standard, this requirement results in animosity between the supplier and the government. This is not a desirable situation from the industry's point of view. Commercial companies have a good reputation to uphold. This is sufficient incentive to fairly price products to the military. We suggest that commercial companies (i.e. less than 20% total sales to the military) be exempted from these regulations.

The Advanced Technology Program in the Department of Commerce is a helpful step in supporting civilian R & D. We look forward to its planned request for proposals.

We want to also thank you for the formation of the Congressional Advanced Materials Caucus. A number of us are working to assure that this caucus adds to your knowledge of advanced materials and their contributions to society.

For summary, the productivity gain and resulting economic benefits from cooperation between industry, academia and government is too large to ignore. All three have taken action to improve our ability to work together. Further improvement is required. congress can help by recognizing the importance of materials to our society, joining the Congressional Advanced Materials Caucus, backing the National Research Council's Material Science report recommendations, encouraging capital formation and availability, establishing conditional loans in place of contracts, supporting the Advanced Technology Program and reducing the risk created by the special requirements of the military's potential markets.

Mr. TORRICELLI. Thank you, Mr. Dieck, that was a fascinating and very impressive presentation.

Let me begin with you, if I could, representing Dow Corning Wright. You are not exactly an enterprise without resources. How is it someone with the history of your company and these practical and profitable applications of it find yourself in such dependence for these materials, that you have not either found your own alternatives or produce them yourselves under licenses?

Mr. DIECK. Our technology strength is really in the area of polymers, in particular, these silicones, and the first three devices that I passed by you are examples and those literally are our leading edge. When it comes to metals and composites, it's outside of our parent company's technology base, so we are dependent upon vendors for that.

Mr. TORRICELLI. Well, forgive me, but that appears to me to be classic American business answer. No doubt it is outside; no doubt a few years ago it was outside of everybody's expertise. It appears that some, unfortunately. in your industry, apparently many of them not located in this country, decided to expand their expertise.

Mr. DIECK. Correct.

Mr. TORRICELLI. Help me understand. Why is it an executive of your company, recognizing the future in this industry, and your important role you play in it, would not have made the strategic judgment in the company, given your resources and your presence in this business, to develop that capability yourselves?

Mr. DIECK. The metal—

Mr. TORRICELLI. Whoever you're buying them from does not have the resources you have.

Mr. DIECK. Actually they—actually the individuals we're buying from have more resources—

Mr. TORRICELLI. Who was the French and the Japanese companies making those?

Mr. DIECK. Tory Industries is the Japanese company and SEP is the French company.

Mr. FENTER. Nation of France.

Mr. DIECK. Yes, the Nation of France.

I want to—I think—

Mr. TORRICELLI. That serves to make another point.

[Laughter.]

Mr. DIECK. I think I need to stress the medical device business is such a small-volume business. The capital investment in order to get into the carbon-carbon business or the ceramic business is so huge that without having access, as kind of a side business, to the aerospace business, there's no way—

Mr. TORRICELLI. You yourself defined the medical technologies as a $50 billion enterprise.

Mr. DIECK. Right.

Mr. TORRICELLI. I would—one would think that some of these advanced materials have cross applications for a variety of products.

Mr. DIECK. Correct, they do. The business—the overall business is $50 billion. The implant business, of which I share these examples here, is probably more in the neighborhood of 2- to $3 billion, so it's fairly small in terms of aerospace dollars.

Mr. TORRICELLI. And not only do you not make these materials under licenses from French or Japanese companies, you're actually buying the raw product itself?

Mr. DIECK. At the moment, we are purchasing the product. We are in negotiations to license the carbon-carbon technology.

Mr. TORRICELLI. Let me could, the, if I could, to the panel, if—if I might, are we at the point with the National Aerospace Plane where any of the composite materials or other advanced materials in it have us in a place of dependence at this point?

Mr. GULCHER. Dependence, sir?

Mr. TORRICELLI. Yes.

Mr. GULCHER. In carbon-carbon, as mentioned earlier, the fibers do come from overseas and that is true. The one possible other area is the silicone carbon fibers where there's only one source at this point. In fact, that's been true with things like boron fibers and others. That's Textron in Massachusetts. That is the only supplier, although, as part of the Aerospace Plane, we are trying to develop additional sources for those so that is a concern, but certainly it is available now.

The tiluminides and things of that sort are made in this country. In fact, they're rolled by people like Timed, RMI and others.

Mr. TORRICELLI. Nevertheless, we are already over the threshold of some element of dependence in the—

Mr. GULCHER. There is some element of dependence, just as there is in all of the carbon—you know, composites, yes, sir.

Mr. TORRICELLI. In which—in which component parts of the aerospace industry would foreign leadership in the development of the basic technology and the parts, manufacturing the parts, be most evident, looking at the overall product? Where are those leads now clear?

Mr. GULCHER. You're talking now about aerospace products—

Mr. TORRICELLI. Aerospace industry only.

Mr. GULCHER. —particularly like space kinds of things and things of that sort?

Mr. TORRICELLI. What I'm talking about is at the moment, would you say that the—the foreign penetration of the industry thus far is on the alloys and the engine side or on the airframes, the composites on wings? Where is it this is showing up most competitively?

Mr. GULCHER. I think today, you would still say the United States is leading in most of those areas.

Mr. TORRICELLI. I understand, but that's not the question. The question is where is it now showing up first? Where are the first indicators?

Mr. GULCHER. I think probably the only one that I—comes to mind is, again, this SEP company in rockets, particularly in some—again, in the carbon-carbon kind of structures they've done, it's very impressive.

In some of the other areas, I guess I'd still have to say that we're probably leading in those.

Mr. TORRICELLI. Have any of you been approached by the National Council and asked for recommendations or to participate in development of this plan or report, as it might be?

Mr. FENTER. We have not. Of course, as I mentioned, in the case of the AIA, technologies for the '90s, for the year 2000, I mentioned that Dr. Bromley is a member of our Policy Forum. Other than that, I don't know of any other interaction with that Council.

Mr. TORRICELLI. Have any of you been contacted, participated in the development of this report/plan?

Mr. GULCHER. I have not. No.

Mr. NEWKIRK. In my own case, I have not appeared before the Council, if you will, but I certainly have met specifically with Dr. Bromley and discussed the issues of our industry.

Mr. TORRICELLI. Are each of you generally supportive of the notion of a national initiative along the lines of others that have been attempted of a private government consortium to separate out roles, responsibilities and basic research? Are we at that part of the development of a solution?

Mr. GULCHER. I think in terms of the National Aerospace Plane, obviously, the consortium—

Mr. TORRICELLI. I was thinking about the problem of industry, advanced materials generally.

Mr. FENTER. I think the fact that in the case of advanced composites, the fact that industry, on their own initiative, have undertaken the program I described indicates that we must support it because we're doing it all with our own money, the ultimate test.

Mr. TORRICELLI. That motivation I understand.

Mr. FENTER. Right.

Mr. TORRICELLI. I was looking at another one, which is that—not simply that one could substitute government money for your own—

Mr. FENTER. Sure.

Mr. TORRICELLI. —but the notion that without it, without some cooperative effort in assigning responsibilities and in sharing your resources and ours, we simply are not going to succeed. Has that judgment been reached individually in companies so that you find yourselves where some of we believe we now are with semiconductors and other such problems?

Mr. NEWKIRK. Mr. Chairman, with respect to the United States Advanced Ceramics Association, we've certainly come to the conclusion that a government involvement strategically with the industry is critical to enabling its competitiveness. I—we have not come to a conclusion that a shared technology effort, in terms of some general consortium, is the correct solution to that. However, we certainly have come to the solution that strategic government involvement in funding critical programs, in providing critical markets to enable us to bridge the gap which I described, is altogether critical to the competitiveness of this industry.

Mr. TORRICELLI. Finally, for my part, is there a—anything on the patent side that Congress could be doing which would be effective or helpful? Is that an element here and whether it is speed or definition or protection? Is that not an element of this problem?

Mr. GULCHER. From our standpoint, it is not.

Mr. TORRICELLI. It is not?

Mr. FENTER. It is not.

Mr. TORRICELLI. Mr. Dieck?

Mr. DIECK. Mr. Chairman, from our perspective, it is an issue. I—in government programs, traditionally, the government has—in

those areas of technology which it has funded, has required a license to go to the government on at least a nonexclusive basis to practice the technology. In those cases where the government represents the critical enabling bridge market, it serves as a disincentive for the industry to then invest its own money in commercializing the technology with regard to using that bridge market.

So we believe that, in fact, there are things which can be done.

Mr. TORRICELLI. I should note on the patent side that it was through the good graces of the Northrop Corporation, which deserves honorable mention, that they allowed some of their own composite materials to be used to substitute heavier materials in the America's Cup, allowing us to whip those international competitors that we faced and they deserve that honorable mention.

Mr. DIECK. Mr. Chairman?

Mr. TORRICELLI. Yes.

Mr. DIECK. From a medical device standpoint, we have already been afforded additional protection through Congress by way of extension of the patent law, due to regulatory considerations.

Mr. TORRICELLI. How long are we from the time when the natural alloy dependency that we have in jet engines technology could genuinely be behind us because of advanced materials? This problem that we now experience, whether it is from Africa or potentially in the future from the East, of natural alloys? Is this something that we can realize in the near future and be free of this strategic problem?

Mr. FENTER. I don't think it's anyone's opinion that we can be free of the problem in the very near future, but it'll be a long-term effort. However, if you don't start, you'll never get there.

Mr. TORRICELLI. On that we can agree.

Mr. Rohrabacher.

Mr. ROHRABACHER. Yes, very quickly, I would like to note that Mr. Newkirk suggested that the Defense Department was very important to the development of these new technologies and the contracts that they've had in the past have spurred on technological development. I don't think that we should forget that when we start—when we have in mind how much we're going to be cutting the Defense budget in the name of a peace dividend. And I know that this Congressman isn't going to forget that and that perhaps—I also would like to suggest that with the progress that we've seen in the NASP, a project of—this demonstrates two different approaches to progress in this area, to technological progress, that one area, when we're talking about a government-guided technology development versus a project-oriented technology development, and it is a—two different approaches and two different philosophies and I certainly respect the chairman and other members on the other side of the aisle who have a philosophical difference with me in terms of the approaches on how to best—how America can best meet the challenge, and I just would like to applaud the National Aerospace Plane project as an example of when you get people working on a specific project, how they themselves will come up with the technological advances that will keep America competitive in the future and just if—if any of you would like to comment on that, please feel free. But don't feel like you're going to make an enemy out of the chairman by siding with me on this

important philosophical position, but just if you have any comment on that at all? Rather than a broad-based approach and a government program that's broad-based, instead of project-oriented, and I'm specifically saying that a project-oriented strategy would probably be more effective.

Mr. GULCHER. Well, that's certainly true in the National Aerospace Plane, but it accomplished quite a large number of things. It isn't, you know, all that specific because we covered a rather broad range of materials. But I think there's such tremendous enthusiasm, you know, not only for NASP itself, but materials as well, and we have a tremendous number of very fine people that have been working that.

Again, there has been a true government partnership in this particular case, so I think that is a lot of the elements of making, you know, successful, certainly advanced materials and other things.

Mr. FENTER. I would like to make a comment, too, that relates to that and also has to do with how long it will take to remove our dependence on some of the strategic materials.

We all tend to focus on the creation, the research, the development, the evolving of the technology and so on. We sometimes forget that to incorporate a new material or a new composite in particular into an industrial product has profound implications. It means that you have to recapitalize your whole plant frequently, a whole new massive investment in machine tools. It means retraining a labor force sometimes and these things are evolutionary in nature, usually, rather than doing it all at once, except there are cases where a large project gets a lot of those problems behind you in a concentrated way.

I mean generally, it has to be a slow process unless you have unlimited funds.

Mr. NEWKIRK. It's certainly been the—the conclusion of our members in the advanced composites industry that the industry is driven by markets. Our availability and cost of capital is driven by markets and developing technology alone, while it's a very important element of the equation, doesn't, in fact, enable competitiveness by itself. In fact, we need markets for products of that technology and we need markets which are "bridge markets" for economically immature technology to drive our investments and drive ourselves down that experience curve.

Mr. ROHRABACHER. Thank you very much.

Thank you, Mr. Chairman.

Mr. TORRICELLI. Mr. McCurdy.

Mr. MCCURDY. Thank you, Mr. Chairman.

With all due respect to my colleague from California, I think he misses one point, and that is, I'm not the issue's a project-specific versus general technology. I think there's a fundamental ideological gap that's existed in the administration for the past 10 years. I've been playing with this wheel for about five years now. When I chaired this subcommittee, I was spinning it then and as we all spin our wheels in government, as we dealt with the issue of the advanced gas turbine engine, which was a specific program.

We wanted to double the budget astronomically. We wanted to raise, what, $6 million, I think, from 3 to 6, to do work on the advanced gas turbine engine. But since that wasn't part of the De-

partment of Defense, the administration threatened to veto the bill.

Now, if I were—wearing my other hat in the Research and Development Subcommittee of Armed Services, which I sat during that time and still do, we were throwing literally $43 billion—that was our budget—billion, not million, $43 billion, and if I had said this was critical technology for a jet engine, then we could have tripled it and no one would have raised a question.

The point is that there is a philosophical gap that if it's defense, it's all right for the government to be involved. If it's commercial, then you're out on your own. The Japanese don't care whether it's defense or commercial. The Japanese are in the business of making these, and they're not quite waiting for the market to develop totally. They do wait. We win Nobel Prizes; they win the market share, but there's a—there's a difference there. They—they reach that gap quicker; they close that gap quicker than we do because they have the manufacturing base. They are specialists. They see a project and they go after it.

I think that's where we go wrong. I wish I'd been here for Mr.—Dr. Bromley. I say that—we've had him before our committee a number of times and he's one of the most loquacious and delightful scientists I've ever heard, but quite frankly, the fact that it's taken them six months to convene the Council, which we for five years have been trying to get them to convene, says something about the continued philosophical and ideological bent to the administration which refuses to deal with this issue.

Mr. TORRICELLI. Rest assured, the point was made.

Mr. MCCURDY. I'm glad the chairman has taken to the chair very aptly, because it has been a continuing problem for this subcommittee and I think the Congress as a whole.

It's one thing to say good things about all the intent, but it's another thing to put your money where your mouth is and the administration continues to refuse to put their money where they think the problem lies.

Dr. Fenter mentioned a couple of things and I know Mr. Gulcher, too, through NASP, and I guess, to prolong it for just a second, we talked about project-specific programs. The gentleman from California, who was very helpful in securing authorization for NASP—but we had to do so almost over Mr. Chu's dead body and Mr. Beatty, at the last minute, fortunately weighed in and agreed—it took them forever to come to a decision.

Your consortium almost evaporated by the time we got their support. So I'm all pleased, but quite frankly, I'm getting tired of hearing all the ideology. I want to see a little more specifics and I think that's all the American consumer wants to hear as well.

The question I have is is the issue of integration and technology. As the defense budget shrinks and it's going to shrink if the trend continues in Eastern Europe and the Soviet Union, as the threat diminishes. As we look at how protect our technology base and our R&D base, I have to—a lot of people are talking about conversion of technology. Don't worry, we'll just make—take all these defense plants and we're going to get them into the prosthetics business or whatever, prosthesis.

I don't think it's as easy as that, and I would like, while we have this panel before us, to take just a minute or two and outline some of the institutional impediments and barriers to transfer—moving from one area of technology to another and the question—you know, what are all these airframers going to be doing in the next 10 years? There will be fewer airframes, I know that, but what—what are some of those barriers and do you have any suggestions of areas that perhaps the government, in the effort to try to facilitate and lessen the impact of these defense cuts in our industrial base—any suggestions that we might have?

The gentleman from California, again, might be interested in the numbers of jobs that might be lost in his area of California if the defense budget declines at the rate that I expect it to decline, and there's not a better integration of technology and these folks aren't becoming more flexible?

Mr. GULCHER. I think some of that, at least in our case—I used to be Vice President of Engineering during the B-1 program. I came out of that program. I became, you know, program manager at NASP, where I pulled together a team of our space people and aircraft people, so now you're seeing a number of aircraft people really contributing significant amount in system integration, materials and all of those in more of a space-like project called NASP, and that's been a lot of strategy in our company, is to take these people who did a tremendous job on a program like the B-1 and be able to utilize those in a very constructive way, you know, in space projects, so in our own companies, I'm sure all of you know, that has been the strategy and that is the things we're doing.

We're still a growth company. We consider ourselves that and we try to use these kinds of materials in other kinds of technologies throughout the company, so that's particularly the way Rockwell's been responding to the particular issue you're mentioning.

Mr. MCCURDY. Well, assuming we go to Mars or assuming we have a space station, assuming that the NASA budget is held—

Mr. GULCHER. I might mention—glad you brought that up, actually a lot of these things we talk about, like NASP, the stability of funding would be tremendous, you know, to keep a lot of these things on track, you know. We went through last year—I know personally, I did a lot less developing, a lot more defending, and these are things that do occur and do have a tremendous impact on the development of advanced materials or anything else. So stability of funding, particularly in these development programs, I think is extremely important. It's the kind of things that our competitors overseas do have in most cases and they seem to, you know, look at those and say, "Gee, isn't that nice?" They continue to get their funds and they seem to be accomplishing a lot, so within our own, you know, deliberations as to what you keep and what you don't, certainly a lot of these technology programs should become more stable, rather than less.

Mr. FENTER. Of course, the question you ask is the number one question in every strategic planning session going on in the aerospace industry in America today. There are no easy answers. We all know that.

There may be some answers that people aren't willing to reveal to their competition, but the—traditionally in our industry, we

have in periods of declining defense budgets, have looked to other areas, but still government funding, like the space program, the Apollo program. If that hadn't happened, I don't know what state our aerospace industry would be in today.

The question is, will it happen again? Will there be things happening in terms of the space station, National Aerospace Plane that will help take up the slack? I think it's very important from a technology base point of view, at the very least. Now, in terms of gross national economics and international competition, it's going to take an awful lot of space activity and an awful lot of National Aerospace Plane activity to take up the slack of the defense budget decrease that we're looking at.

We're all trying to address that problem, as you know, but I don't think anyone has the answer. The other place we have traditionally looked in the past in periods such as this has been the infrastructure. When you have high defense funding, we traditionally have tended to neglect the national infrastructure, if you will, and it's a place we begin to look at when that budget goes down.

I am not proud to say that my company is one of them that lost a lot of business in the people mover ground transportation business some 25 years ago, but I'm not alone. Nearly all the other aerospace companies did it, and that was too bad. That wasn't handled very well. I can't tell you what went wrong, but it really wasn't handled too well. It represents an opportunity for the nation to great improve its infrastructure, especially in the area of transportation, ground transportation, railroads and that sort of thing.

I think we kind of flunked the course that time. Maybe we won't do it this time.

Mr. McCURDY. Dr. Fenter, I'd hate to take a bet with you now about the future of NASP and the future of MAGLEV and within this—because the ideology again the fact that, of course, it's—thank God it's been rare, but we haven't doubled the national debt and it took us 200 years to get there when we do it in the last 10. So we've tied our own hands when it comes to having the flexibility to deal with some of these issues and you still have this impediment. You still have this structure there, though.

I don't think NASP will be in the POM. I think we're going to have to fight it every single year. There's not going to be the stability, the five-year plan that you would like. I think that it's true in a number of these areas, so I'm not sanguine about the potential. I think it's a constant struggle for us and I think that—I really thank the Chair for having this hearing. It's one of our better hearings, very informative, and it continues, I think, a dialogue which we've had to have now for some time, but it—we need to keep the pressure on.

Mr. TORRICELLI. Mr. McCurdy, since this is already known as the most unabashedly partisan committee of the entire Congress—

[Laughter.]

Mr. TORRICELLI. —if Mr. Rohrabacher would forgive me, I just hope it occurs to some of your executive board members and stockholders that in the great national debates about moving from defense spending to investing in infrastructure and in a government role in ensuring that our resources to help our companies move

technology forward as you compete with the French Government and your materials, that there is a constituency in this Congress that believes in that philosophical change very strongly and is fighting for it very hard. It also crosses party lines, I will be happy to concede, but there is a constituency for it.

We just need American industry that has some credibility on this issue greater than we do to become allies and push the issue forward.

Mr. McMillen.

Mr. MCMILLEN. Thank you, Mr. Chairman.

Just a quick question in listening to what you're saying. I'm just curious, what happens if we stay the course as we have been pursuing the last several years, which has been not very aggressive in terms of a national advanced materials program? What happens 10 years from now if we stay the course?

Mr. GULCHER. I think again, as we said earlier, the foreign competition will catch up in many of these areas. In fact, in some areas, they have, and I'd say that that would increase

Mr. MCMILLEN. In a 10-year timeframe?

Mr. GULCHER. I think that could happen in 10 years. Typically—Mr. Newkirk pointed out that the—it takes like 10 years or whatever for new materials to go into production and certainly that's within that time period that you're talking about, so, yes, I think they could overcome, you know, a lot of our advantages at this time.

Mr. NEWKIRK. Certainly our industry position is that this battle will be won or lost in the next 10 years and in the next 10 years, dominance in the area of advanced ceramics alone, in our view, will drive, one direction or another, the competitiveness of the auto industry, of the aircraft engine industry, of the airframe industry, of the electronics industry and many, many other industries in this country.

Mr. MCMILLEN. So basically what you're saying is that if we don't change course, we will, 10 years from now, find ourselves falling dramatically behind competitivenesswise in the automobile industry, the aerospace and everything else? I mean, that's the obvious, is that correct?

Mr. FENTER. I think I agree with that.

Mr. MCMILLEN. Pardon me?

Mr. FENTER. I said I think I agree with that.

Mr. NEWKIRK. I think our position would be, in fairness to the Congress and the administration, we are doing some things right right now, we're just not doing enough of them. And I think we need to stem the trend right now of loss of key industries for the United States, but I think what we need is more in the way of technology development, demonstration programs and more in the way of transition markets to ensure the competitiveness in these key areas.

Mr. MCMILLEN. If what you're saying, and presumably you are in the front lines of dealing with this, is true, why—what are—why are OMB—why are the administration so reluctant when they realize that this investment, this coordination is so important for this country's future? Why are they so reluctant in not being—in not

being more aggressive? Why are they so passive with regard to this whole issue?

Mr. NEWKIRK. If I could offer a comment on that, I think to a fair degree, this is less of a partisan issue and more of an educational issue. I think that there is a common belief, for example, amongst many that the U.S. industry lacks vision, and is lazy or sloppy or stupid or something, and the fact of the matter is that the U.S. industry has an incapacity to make long-term strategic investments on the same basis as our foreign competition. Our ownership structure is one where today the average U.S. industrial has more than half of its ownership owned by institutional investors whose sole measure of success is short-term financial return.

Those CEOs who were willing to make longer-term strategic investments, cut dividends in order to do that, are a thinning number, given that ownership structure. I believe that, very much, there's a need for education on this subject.

Mr. MCMILLEN. So you attribute it to a lack of understanding, lack of information, lack of education?

Mr. NEWKIRK. I believe in part that's correct. I believe there is not a total understanding generally on the part of the—the public or the government that the U.S. industry is specifically disadvantaged with regard to its capacity to make long-term strategic investments in this area.

Mr. GULCHER. Could I add? We talk about, you know, these various ways and we say that perhaps the—what has happened has not been, you know, all that good. I still look at the tremendous source of R&D that has already been accomplished, you know, by DOD and others, and frankly, it's phenomenal. I mean, there's been a lot of money put in. There's a lot of good work, and I think typically, and you read this in the papers and everything else, that the U.S. is very good at coming up with ideas, but the problem has been more of exploiting that, you know, in applications.

And I think that's what Dr. Bromley said earlier, that our problem today is more in synthesis than production. That's what NASP is doing. It's integrating technologies; it's pulling them together and making all of the things that the government—in the past year, it's done very good work. It's pulled that together and making good applications of that into products for the future.

So I think it's more that. You know, it's not a one versus the other. I think there's a lot of good R&D going on and there's a lot of scientific things going on in the materials community. The knack is now to be able to get these projects and get them focused, get them oriented towards applications and doing the synthesis and production.

Mr. FENTER. I would certainly agree with what Mr. Gulcher says, and you ask—Mr. Chairman, you asked Dr. Bromley, I believe, a question having to do with how our European competitors, for example, invested in R&D. Well, as a personal observation, in the last three years, I've become very alarmed through the process of traveling in Europe, as well as Japan, and being briefed by various companies on their R&D programs and the reason I became—I've become alarmed is that when they talk about R&D, total R&D investment, they talk in terms of R&D as we know it, but including manufacturing R&D, but they also include their capital investment

in new plant equipment and new product development, the whole thing, including capital investment.

And you take those companies on the whole and you add the equivalent to our R&D type of investment to their capital investment in new equipment and factories and that adds up to 13-, 14-, 15 percent of their annual sales, and many of those companies—in France, you say, "Gee, how can we beat that," but then, on the other hand, most of their high-technology industries are either nationalized or partially nationalized and we don't want that, for sure, but on the other hand, when you go into West Germany and visit various companies, you hear those same times of—same types of numbers quoted and they're certainly not nationalized. However, they are aided in various ways by their governments. I can't tell you exactly how, but it's a very cooperative situation over there.

But what I do know is that if you take those numbers and add them together in this country, if you get 9 percent, you know, that's considered a pretty healthy number, compared to their 13-, 14-, or 15 percent. Do that year after year after year after year, you're going to see big differences, no matter what.

Mr. TORRICELLI. And we do.

Mr. FENTER. I find that very alarming. What's the answer? I don't know.

Mr. DIECK. I'd like to echo that comment. I really believe, in particular in Japan, that R&D expenditures are defined in a different way than they are in the United States. It's, if you will, commercialization expenses. It's the whole package, capital investment on through to the product that's to the consumer, which is an entirely different definition.

I guess I'd echo one other thing and that is, in particular, in Japan, and I notice you have a couple of things up there in front of you—I think there's a willingness on the part of not only Japanese companies, but also European companies, to expand—they have the latitude to expand beyond what their base business is.

So you get ceramic aerospace companies—

Mr. TORRICELLI. Why do they have a capacity that our companies don't have? You said an aerospace company that has this technology, this material, and decides to license it or sell it or make it for someone who's in the business, or goes into the business, why doesn't that happen?

Mr. DIECK. I'll give you my two cents. I really think it's a focus on a national level on specific technologies and participating in specific segments of the uses of those technologies, is number one, and number two, I think it's a different way of—from a business standpoint of perhaps looking at bringing a product forward, and that's based on margins, rather than profits.

Mr. TORRICELLI. For most of this hearing, I have faulted the government for not being involved in bringing forces together in the country, but private industry is not without fault in it, either.

Mr. DIECK. I'd agree.

Mr. TORRICELLI. But my answer to the question I posed is a lack of aggressiveness in the culture of business, and that is to exploit every opportunity to enter any field where there is a profit to be made, whatever technology is at hand. I run into this all the time. People who are in a certain industry and they have an idea that

can be applied to a different field and you ask them why, and they say, "We're not in that business."

Well, are you in the business of making money?

[Laughter.]

Mr. TORRICELLI. That has not often—always been true in our country. It is true today. I don't understand it, but it is something that we're not going to legislate away, this aggressiveness that has to come in the national business spirit.

Mr. Rohrabacher, you have the last question.

Mr. ROHRABACHER. All right, and I'd like to compliment the chairman on these hearings, as well, and I also would like to underscore his words about bipartisanship and a commitment to technology and technological advancement. There are a few philosophical differences, but actually those are very, very small compared to what some of the philosophical differences are in other committees and others parts of this Congress and I certainly compliment him on putting this hearing together today and I know we will be working in the future to try to overcome some of the problems that we've been talking about.

But the reason I asked for a chance here at the end to ask one last question, and it was stimulated by what Mr. Newkirk said just in passing, and we have heard on many occasions that in America, we have lots of technology, we have lots of new development, but we have very little application and that the Japanese are constantly apply—taking our technology and applying it. We just heard—I guess with the carbon-carbon that we were talking about earlier, and just even today, we've heard of examples of that.

So I—and your comment about institutional investors. There has been a major change in ownership of the—of our corporations throughout the United States, not just in aerospace and technology, but all throughout, and I think that this may have some of the—this may be the root cause of what the problem that you're discussing, Mr. Chairman, and I don't know if any of—are any of you aware of the bill that has been presented on the Senate side that would encourage more employee ownership of our major corporations, especially our aerospace firms?

I believe in employee ownership and I believe that today, when you have capital that—when you have management that goes in and out of management jobs and jumps from one company to another, they have a short-term approach and when you have capital flowing in and out of corporations and they have a short-term approach, that perhaps expanding the ownership base of the employees, who, after all, have a long-term approach to their company because they're concerned with their pensions, which is a long-term concern, that perhaps this could have some impact on our companies' ability to make the long-term capital decisions in order to get into new product lines and such as that which, of course, costs some money in the short term, but may bring profit in the long term.

Mr. Newkirk, do you have any comment towards that?

Mr. NEWKIRK. Yes. I personally believe that the—that the ownership structural differences between the United States and North American companies in general and European and Asian companies accounts probably more than any other single factor for the

difference in capacity and inclination to invest long-term in strategic investments.

I—when you're a CEO of a company—if you were a CEO of a company two decades ago and you had the greatest breakthrough in history, you could go to your constituency and you could explain it to them, and they were individual shareholders and your—the price of your stock would not drop, and they would not cash out of your stock because you were cutting the dividend to make some strategic investment in this major breakthrough.

Today, if you're a CEO of a U.S. corporation, differently than 20 years ago, more than 50 percent of your stock typically is held by institutional investors, and when you make that same speech, it doesn't even matter if they believe you because their constituency votes by cashing out of their mutual fund or whatever, if they cut their short-term earnings rates. So you cut your dividend and the price of your stock will go down.

That is not the case in Europe. It is not the case in Japan, and overcoming even all of the differences in cost of capital and capital leverage and everything, I think that, more than any single factor, is—

Mr. ROHRABACHER. Do you think employee ownership might be a—and encouraging through tax incentives employer—greater employee ownership would be a positive factor?

Mr. NEWKIRK. USACA has no position on that; and my own position would be I think it would, yes.

Mr. TORRICELLI. Mr. Rohrabacher, I'm glad that you have adopted Aesop plan for corporate ownership, but I'm glad you did so after you left the Reagan White House.

[Laughter.]

Mr. TORRICELLI. You would have found your desk on the street, but it is a good position to take.

Also, thank you for—you consistently are our most diligent committee member.

Mr. ROHRABACHER. Thank you.

Mr. TORRICELLI. Thank you for spending time with us today.

Gentlemen, thank you for your cooperation today and your testimony. Let me say, for the record, it is not pleasing to this committee that we have received your testimony, your rather thoughtful ideas about this industry, to hear that those in the administration responsible for drafting a plan of national action have not sought your views.

If, indeed, as this committee returns to this subject, which it will, and receives the report, which it certainly will, and that continues to be the case, that the views of industry have not been sought, and your views are not included in that product, I, for one, will be very distressed and not receiving it well.

I thank you again. The committee stands adjourned.

[Whereupon, at 4:42 p.m., the subcommittee was adjourned, to reconvene subject to the call of the Chair.]

○

34-733 (104)